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SCHUH · Exchange Rate and U. S. Agriculture
JUST · Risk in Farmers' Decisions
EVANS · Price Adjustment and Market Stability in the U. K.
TALPAZ · Multi-Frequency Cobweb Model
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SHORT ARTICLES AND NOTES

SAYLOR—Supply Elasticities for São Paulo Coffee
TRYFOS—Canadian Supply of Livestock and Meat
SHERBINY AND ZAKI—Agricultural Development in Egypt
ANDERSON—Measurement of Buyer Brand Preference
SPORLEDER AND WILSON—Credit Card Purchasing
DAVIS AND HILL—Spatial Price Differentials for Corn
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# The Exchange Rate and U. S. Agriculture*

G. Edward Schuh

Previous analyses of trade and development problems of U. S. agriculture have neglected the role of exchange rate policy. An attempt is made to understand the role of the exchange rate on these problems in a non-parametric fashion by means of a model of induced technical change. It is argued that the overvaluation of the dollar and the policy measures to combat it aggravated the adjustment problems of U. S. agriculture, especially during the 1950's, and resulted in shifting an important share of the benefits of technical change to the consumer. Moreover the recent devaluation of the dollar constitutes an important structural change for U. S. agriculture.

*Key words:* Exchange rate; agricultural adjustment; agricultural policy; technical change; trade; development.

Agricultural economists have given considerable attention in the last two decades to analyzing and understanding the set of economic forces which gave rise to what has euphemistically been called "the farm problem," and to proposing policy alternatives for its solution. Perhaps the most commonly held interpretation is as follows. The U. S. has invested heavily in the production and distribution of new production technology for the agricultural sector. This caused the supply of agricultural products to increase faster than demand,[1] with a consequent decline in agricultural product prices to unacceptable levels. The presence of a politically powerful farm bloc resulted in price supports for politically important products at levels above the equilibrium price. These high prices gave rise to surpluses which burgeoned rapidly.[2] The cost of acquiring and maintaining these stocks, together with their obvious conspicuousness, gave rise to political pressures against them. By the time that such pressures had built up, the political power of the farm sector had declined, and the U. S. had a president (John Kennedy) with strong urban interests. A shift was made to price supports that were flexible downward, and supply was brought closer into balance with demand by land retirement schemes. In addition, efforts were made to increase utilization of excess production by domestic disposal programs to help the poor. Parallel measures were taken to dump part of the excess production abroad by means of foreign assistance programs and export subsidies to commercial sales.

One of the as yet unexplained paradoxes of this situation was that the country with perhaps the most technologically advanced agriculture in the world had to subsidize its agricultural exports, or to dispose of them outside commercial channels. The usual explanation for this phenomenon is that the U. S. has *over*-valued its agricultural resources (and in turn the products they produce) by means of the price support programs and the land retirement schemes. The combination of high land values (representing a capitalization of the support and land retirement programs) and high labor costs (characteristic of a developed country) were believed to cause domestic products not to be fully competitive in world markets. In addition, it has been believed that trade barriers by other countries against U. S. agricultural exports justified the use of export subsidies and other devices to maintain the U. S. position in world markets.

This author is convinced by his reading of the literature that a very important variable has been left out in the conception of this problem and that at least since the early or mid-1950's the definition of the problem has been at least partially wrong because of this omission. The omitted variable is the exchange rate and its role in trade, in the valuation of resources within the U. S. economy, in the distribution of benefits of economic progress between consumers and producers within an economy, and

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[1] The lack of adequate labor mobility and the fact that uch of the new technology was imbedded in new capiál inputs is believed to have complicated the adjustment of resources out of agriculture that would naturally have taken place.

[2] High, stable prices are believed by many to accelerate the rate of adoption of the new production technology.

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in the way the benefits of technical change are shared between the domestic population and the world at large.

There are four major propositions of the present paper: (1) that an important share of the income problems of U. S. agriculture in the post-World War II period was a result of the persistent over-valuation of the U. S. dollar, which resulted in an *under*-valuation of our agricultural resources in relation to their world opportunity costs; (2) that the stress caused by this under-valuation forced a more rapid rate of technical change than would otherwise have been obtained and that this in turn aggravated what would have in any case been a serious adjustment problem; (3) that the over-valuation of the dollar resulted in a larger share of the benefits from the technical change being channeled to U. S. consumers than would have occurred with an equilibrium exchange rate; and (4) that the sizeable devaluations of the last two years[3] and the movement to essentially flexible exchange rates constitute important structural changes for U. S. agriculture and the U. S. economy. This paper is for the most part an exercise in analysis, and its major propositions are offered in large part as hypotheses to be tested with further research. Hopefully, however, the analysis does provide a framework from which the current and past agricultural situation can be better understood.

The next section contains a brief exposition of some of the relevant theory. This theory is then used to interpret the development of U. S. agriculture in the post-World War II period and to provide a characterization of the changed structural environment of agriculture as a result of the devaluation.

## Theoretical Considerations

The major theoretical issues involve a consideration of three factors: (1) the consequences of an over-valued exchange rate on the agricultural sector; (2) a model of induced technical change; and (3) an analysis of the distribution of the benefits of technical change between consumers and producers. The first two will be considered in some detail.

### The consequences of an over-valued exchange rate

Consider agriculture in the aggregate, and assume that at prevailing economic conditions it has the potential to be an export sector. The conditions governing the industry will be as illustrated in Figure 1. *SS* and *DD* represent the domestic supply and demand conditions, respectively, and $I_D$ represents the international demand for agricultural products, drawn on the assumption that the country is unable to influence the price of its exports,[4] and assuming that the exchange rate is in equilibrium.

If $I_D$ prevails, the domestic price will be $P_1$ and will be determined by the foreign market and by the long-run conditions of supply in other countries. Under the conditions portrayed, the quantity produced would be $Q_2$ and the quantity demanded domestically would be $Q_1$. The quantity $Q_1Q_2$ would be exported at price $P_1$, and total exchange earnings would be $Q_1ABQ_2$. Gross income to the sector would be $OP_1BQ_2$, with $OP_1AQ_1$ coming from the domestic market and $Q_1ABQ_2$ coming from the foreign market.

Now assume that the currency for this country is over-valued. The consequence in domestic terms is to shift the $I_D$ curve downward ($I_D'$), other things being equal. It is important to recognize that viewed externally, the consequence of the over-valuation is to raise the price of the product in terms of foreign currency, which reduces the quantity demanded. If foreign demand as viewed from the standpoint of an individual country is in fact perfectly elastic, with the price of the product ultimately determined by conditions of long-run cost in other countries, the effect of over-valuation is to shift the international demand curve downward from a domestic viewpoint.

The effect is to lower the price of the product in the domestic market, with the result that the product is under-valued in relation to its

[3] The dollar was devalued in relation to gold by 8 percent in August 1971 and by another 10 percent in February 1973. At the same time there were sizeable revaluations of the currencies of important U. S. trading partners. Estimates of the magnitude of the effective devaluation of the dollar vary a great deal, depending on the purpose for which the measurement is made and the procedures used. One source [6] indicated that the overall, trade-weighted devaluation of the dollar, in relation to all other currencies, was 26–27 percent between July 1971 and June 1973. Another source [18] estimates that the extent of dollar devaluation relative to the currency of 14 major commercial markets for U. S. agricultural commodities, as of May 1973, was approximately 15 percent, while the devaluation relative to major importing countries was approximately 8 percent.

[4] This assumption is made only to facilitate the exposition and does not imply that the foreign demand for U. S. agricultural exports can be so characterized. The presumption in the case of the U. S. is that the foreign demand is very elastic, but not perfectly elastic.

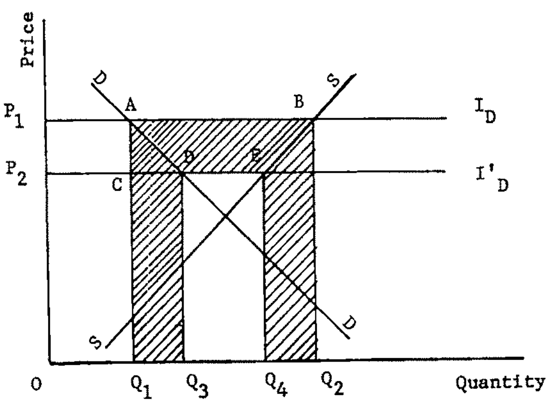


Figure 1. Market conditions for an industry producing for both the domestic and foreign markets

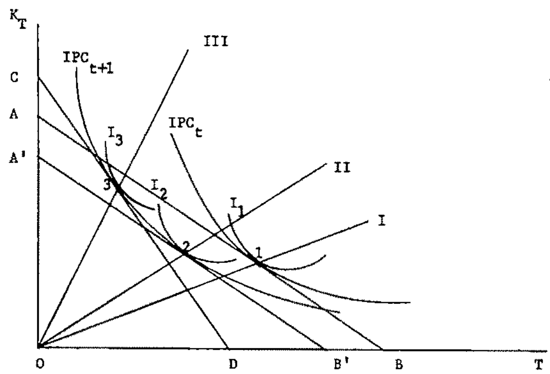


Figure 2. Innovation Possibility Curve and Production Isoquants

equilibrium-exchange-rate, foreign-market alternatives.[5] At the lower price the quantity demanded domestically increases to $Q_3$, and the quantity supplied declines to $Q_4$ as mobile resources are forced out of the industry. Exports are reduced to $Q_3Q_4$, with a valuation to the domestic agricultural sector of $P_2$. The shaded area (Fig. 1) indicates the magnitude by which the value of exports is reduced to the domestic agricultural sector. Moreover, gross income to the sector is reduced to $OP_2EQ_4$, with $OP_2DQ_3$ coming from the domestic market and $Q_3DEQ_4$ coming from the foreign market. The sector may become more dependent on the domestic market, although this will depend on the relevant elasticities and the rate at which the supply curve shifts to the right.

The magnitude of the reduction in the exchange earnings, as well as the decline in gross income to the sector, will depend on the respective elasticities of demand and supply and the amount of over-valuation. If over-valuation is persistent, however, it is the long-run elasticities that are relevant.

## Model of induced technical change

Alain de Janvry's extension [3] of the Ahmad [1] model of induced technical change is particularly helpful in understanding the development process in U. S. agriculture. An important element of this model is the *ex ante* concept of an historical Innovation Possibility Curve (*IPC*), which envelops all presently known or potentially discoverable technical blueprints at a given state of scientific knowledge and which can shift with changes in the stock of scientific knowledge.[6] In the Schumpeterian tradition, technological change can result either from improvements in scientific knowledge or from discovery of new production techniques within the same $IPC_t$.

The basic analytical apparatus is illustrated in Figure 2. A separable, two-stage production function is postulated with the specification of four inputs: land $= T$, labor $= L$, land-augmenting capital $= K_T$ (biochemicals), and labor-augmenting capital $= K_L$ (machinery). Inputs $L$ and $K_L$ are assumed to be highly substitutable, and similarly, $T$ and $K_T$. Substitution possibilities among the sub-functions in

$$Y = F[f_T(T,K_T), f_K(L,K_L)]$$

are assumed to be relatively low, however.

The analysis focuses on the sub-function $f_T$, because land-augmenting capital is assumed to be output-increasing, while labor-augmenting capital is assumed to be labor-substituting and only mildly output increasing. (The economic forces affecting these alternative substitution possibilities are assumed to be relatively independent.) Traditional production technologies would be land-intensive in the factor proportions sense, and modern technologies would be $K_T$-intensive. $IPC_t$ is the innovation possibility curve at the initial time period, and $I_1$ is the production isoquant for a given technique of production along the $IPC$ curve. With the accumulation of scientific knowledge, the $IPC$ will

[5] The over-valuation of the currency is an implicit export tax whose incidence on the domestic economy increases as the elasticity of foreign demand increases.

[6] The *IPC* corresponds to the metaproduction function of Hayami-Ruttan fame [5]. Hayami and Ruttan considered a period of time in which the state of scientific knowledge could be assumed constant, however, while we want to permit it to change. Moreover, they downplayed the role of product price, and we want to give this major importance.

shift to $IPC_{t+1}$. In response to changing economic conditions producers may innovate and move along a given *IPC*, or they may shift to the new $IPC_{t+1}$. Applied agricultural research, either by the producers themselves, private companies, or public institutions, helps them make these adjustments.

Define *AB* as a unit cost line, $P_T T + P_{K_T} K_T = 1$, where $P_T$ and $P_{K_T}$ are the factor prices relative to product price. The tangency of this price line with $IPC_t$ and production isoquant $I_1$ at point 1 is a point of initial equilibrium. Resources are combined in the proportion given by ray *I*, and Schumpeterian profits are zero.

Now suppose $IPC_{t+1}$ becomes available because of continued investments in science. As de Janvry has pointed out, this new *IPC* represents a *latent* demand for new production technology. Whether producers will attain it or not will depend on what happens to product and factor prices, and/or to the installed capacity for applied research which provides the means of discovering new production techniques.[7]

Assume that an adequate applied research capacity is available and that farmers can make their desires known to the researchers. The possibility of reaping Schumpeterian profits will provide an important driving force to reach the new $IPC_{t+1}$. In this move towards the new *IPC*, two benchmark cases are interesting. First, assume that product demand is perfectly elastic (as would be the case if the product were exported and the country had no influence over price) and that land is relatively inelastic in supply. Innovation or the adoption of new production technology on the part of farmers results in Schumpeterian profits. This is equivalent to an increase in rate of return on owned resources. If the capital market was previously in equilibrium, the increase in rate of return to land has to be capitalized in higher land values for the capital market to return to an equilibrium. Adopters will bid up the price of the land, which is in relatively inelastic aggregate supply, until rates of return are again at par with opportunity costs.

It should be noted that in this sense producers receive the benefits of the new production technology and that ultimately its value is capitalized into resources that are in relatively inelastic supply—in this case land. It should also be noted that this changes the factor-price ratio, with the result that the price line *AB* would rotate in a clockwise fashion. This would provide incentive for innovative activities in the direction of land-augmenting technical change and would shift factor proportions to a point along a ray lying to the left of ray *I*. Hence, the land market gives rise to forces promoting technical change, which de Janvry [3] has described as a land-market treadmill.

As a second benchmark case, assume that the demand for the product is inelastic and that the supply of land is relatively elastic. As the new production technology is adopted, output increases. With the inelastic product demand, this leads to a decline in product price, which eliminates the Schumpeterian profits earned by the early adopters and imposes income losses on the non-adopter—a strong incentive for them to adopt also.[8] There will be strong incentives for conventional resources to leave the sector, making for major adjustment problems. In effect, the benefits of the technical change accrue to the consumer and temporarily to the early adopters. Non-adopters bear the burden of the adjustment costs as they are either locked in with lower incomes and returns on their owned resources or sell out for alternative employment. If relative factor prices do not change, the new equilibrium will be at point 2.

It is important to recognize that autonomous changes in product price can be a powerful incentive to technological change, particularly if a new *IPC* becomes available and a strong applied research capacity is available. Rosenberg [8], de Janvry [3], and others have pointed out that stress is an important motivation to technical change. Negative or falling profits that would result from a decline in product price would be a powerful inducer of innovative activity, particularly if a new *IPC* and an installed research capacity were available. Hence, the incentive to move to $IPC_{t+1}$ would be strong, and if the downward shift in prices continued, the need for resource adjustment could be great.

An interesting aspect to the adjustment process follows from this analysis. Suppose the agricultural sector is made up of innovators and non-innovators. Those who innovate will have incentive to acquire more land, since the ownership of land is the key to their reaping the economic rent which will accrue to their scarce in-

[7] Note that all of these except product price are important elements in the Hayami-Ruttan model.

[8] This, of course, is the technological treadmill which Cochrane popularized in the late 1950's. See [2].

novational ability and which is ultimately based on the new production technology made available to them at near zero private cost from public institutions. This should make for an active land market and could result in the bidding up of land values even though product prices are declining. The extent of this bidding up will depend on the mobility of the labor force and the strength of the non-farm labor market. If labor is relatively mobile and the non-farm labor market is relatively strong, the non-innovators would likely sell out and seek employment elsewhere. If the labor force were relatively immobile, on the other hand, and/or the non-farm labor market were relatively weak, land values could rise substantially. In effect, they would have to rise sufficiently to make the capital gains, which the non-innovators could realize, be sufficient to motivate them to take their gains and incur the costs of adjustment to new employment.

## An Interpretation of Post-World War II Agricultural Development

The following analysis attempts to incorporate exchange rate policy or, more specifically, the over-valuation of the dollar, into previous interpretations of the development of U. S. agriculture. The interpretation is tentative and subject to more detailed verification with future empirical research. However, the logic of the case would suggest that the exchange rate has played an important role in determining the kind and rate of development we have experienced.

A key empirical issue is to identify when the dollar became over-valued. It seems clear that the U. S. came out of World War II with the dollar *under*-valued, at least in terms of economic and political conditions prevailing at that time. The dollar shortage dominated policy discussions, and non-price rationing of various kinds developed in exchange markets.

But the evidence is rather strong that at about the time of the Korean War the dollar became over-valued. In the absence of shadow prices, a number of other kinds of evidence can be utilized to benchmark the start of over-valuation and to verify its persistence. The first of these, and perhaps the most immediate, is to verify what was happening to exports. Data on a proxy for this variable—the acreage used for producing export products—is provided in Table 1. Land for this purpose increased through the war years from its low point in 1940 to a first peak in 1946. Although fluctuating from year to year, this relatively high level was sustained through the post-war years and reached another peak in 1951.

In 1952, however, the acreage used for producing exports declined by 39 percent. In 1953 it declined even further, to little more than half what it had been in 1951. (It is significant that the Agricultural Trade Development and Assistance Act was approved in 1954.) Although considerably less than an ideal indicator, this data series suggests that as far as agriculture was concerned, the dollar began to be over-valued in 1952. Of course, one could counter that starting about that time the U. S. priced agricultural products out of world markets by means of the support program. Nominal prices of many exportable agricultural products did rise through 1953 and 1954. However, as the data in Table 2 indicate, the real support price of these products did not rise in this period, with the possible exception of milk products, wool, and sorghum. The alternative explanation is that the domestic inflation associated with the Korean War, and U. S. overseas operations in waging that war, caused the dollar to become over-valued at its fixed exchange rate.[9]

Complementary data which support that argument and which suggest a persistent over-valuation throughout the rest of the 1950's and the 1960's are provided in Table 1. The U. S. gold stock reached its peak in 1949, declined in 1950 and 1951, recuperated in 1952, and then started an almost secular decline. From 1952 to 1955 it declined by over 6 percent, from 1955 to 1960 by 17 percent, from 1960 to 1965 by a whopping 23 percent, and from 1965 to 1970 by a further 20 percent. In addition, the balance of payments was almost perpetually negative from 1950 through 1971 (Table 1). The deficit was sizeable through the 1950's, became larger in the late 1950's and early 1960's, and then after a small surplus in 1968, grew rapidly in 1969 to 1971, culminating in the huge deficit of 1971 which led to the first devaluation and the suspension of convertibility. These data on the gold stock and on the balance of payments suggest both a persistent over-valuation and a tendency for the over-valuation to become larger through time.

A brief review of domestic policy with respect to agriculture is also important in understanding

[9] Another factor contributing to the decline in agricultural exports at this time was the recovery of agriculture in Western Europe.

Table 1. Selected data on U. S. economy and agriculture

| | Crops[a] harvested | Acres[a] for export | Gold[b] stocks | BOP[c] | CCC stocks[d] owned by government | Government[e] payments | Cash[e] receipts | G.P. ÷ C.R. percent[f] | Acreage[g] diversion | Parity[h] ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 1940 | 341 | 8 | 21,995 | 2,890 | | 723 | 9,105 | 7.94 | | 81 |
| 1941 | 343 | 12 | 22,737 | 1,119 | | 544 | 11,655 | 4.67 | | 92 |
| 1942 | 348 | 13 | 22,739 | —206 | | 650 | 16,215 | 4.01 | | 104 |
| 1943 | 357 | 21 | 21,981 | —1,979 | | 645 | 20,265 | 3.18 | | 112 |
| 1944 | 362 | 25 | 20,631 | —1,828 | | 776 | 21,312 | 3.64 | | 108 |
| 1945 | 354 | 42 | 20,083 | —2,737 | | 742 | 22,405 | 3.31 | | 109 |
| 1946 | 352 | 45 | 20,706 | +1,261 | | 772 | 25,574 | 3.02 | | 113 |
| 1947 | 355 | 42 | 22,868 | +4,544 | | 314 | 29,934 | 1.05 | | 115 |
| 1948 | 356 | 52 | 24,399 | +1,006 | | 257 | 30,484 | 0.84 | | 110 |
| 1949 | 360 | 45 | 24,563 | +211 | 1,725 | 185 | 27,990 | 0.66 | | 100 |
| 1950 | 345 | 50 | 22,820 | —3,489 | 1,926 | 283 | 28,744 | 0.98 | | 101 |
| 1951 | 344 | 59 | 22,873 | —395 | 1,206 | 286 | 33,144 | 0.86 | | 107 |
| 1952 | 349 | 36 | 23,252 | —1,080 | 946 | 275 | 32,803 | 0.84 | | 100 |
| 1953 | 348 | 31 | 22,091 | —2,102 | 2,415 | 213 | 31,214 | 0.68 | | 92 |
| 1954 | 346 | 37 | 21,793 | —1,516 | 3,951 | 257 | 30,089 | 0.85 | | 89 |
| 1955 | 340 | 47 | 21,753 | —1,242 | 5,604 | 229 | 29,719 | 0.77 | | 84 |
| 1956 | 324 | 60 | 22,058 | —995 | 5,323 | 554 | 30,955 | 1.79 | 13.6 | 83 |
| 1957 | 324 | 48 | 22,857 | +432 | 4,791 | 1,016 | 30,730 | 3.31 | 27.8 | 82 |
| 1958 | 324 | 44 | 20,534 | —3,529 | 4,692 | 1,089 | 34,545 | 3.15 | 27.1 | 85 |
| 1959 | 324 | 61 | 19,507 | —3,743 | 6,408 | 682 | 34,193 | 1.99 | 22.5 | 81 |
| 1960 | 324 | 64 | 17,954 | —3,711 | 6,079 | 702 | 34,856 | 2.01 | 28.7 | 80 |
| 1961 | 303 | 67 | 16,947 | —2,370 | 5,248 | 1,493 | 36,582 | 4.08 | 53.7 | 79 |
| 1962 | 295 | 66 | 16,057 | —2,203 | 5,271 | 1,747 | 38,103 | 4.58 | 64.7 | 80 |
| 1963 | 300 | 77 | 15,596 | —2,670 | 5,023 | 1,696 | 39,094 | 4.34 | 56.1 | 78 |
| 1964 | 301 | 74 | 15,388 | —2,800[i] | 4,611 | 2,181 | 39,414 | 5.54 | 55.5 | 76 |
| 1965 | 298 | 76 | 13,799 | —1,335[i] | 4,110 | 2,463 | 41,813 | 5.89 | 57.4 | 77 |
| 1966 | 295 | 69 | 13,158 | —1,357[i] | 2,340 | 3,277 | 46,571 | 7.04 | 63.3 | 80 |
| 1967 | 308 | 69 | 12,436 | —3,544[i] | 1,005 | 3,079 | 45,772 | 6.73 | 40.8 | 74 |
| 1968 | 303 | 54 | 10,367 | 172[i] | 1,064 | 3,462 | 47,579 | 7.28 | 49.3 | 73 |
| 1969 | 294 | 61 | 10,367 | —6,958[i] | 1,784 | 3,794 | 51,937 | 7.30 | 58.0 | 74 |
| 1970 | 297 | 72 | 11,105 | —4,721[i] | 1,594 | 3,71[illegible] | 54,239 | 6.85 | 57.1 | 72 |
| 1971 | 310 | 62 | 10,132 | —23,977[i] | 1,118 | 3,14[illegible] | 56,208 | 5.59 | 37.2 | 70 |

[a] *Agricultural Statistics,* 1972: table 654, p. 533. 59 principle crops harvested, in million acres.
[b] Years 1940–1957: *Historical Statistics of U. S.,* Table X299–304, p. 649, in million dollars; 1958–1971: *Statistical Abstract of U. S.,* annual reports.
[c] 1940–1963: Balance of payment, calculated from *Balance of Payments—Statistical Supplement,* Revised. Table 1, pp. 2–4 (millions of dollars).
[d] *Agricultural Statistics, 1972,* table 742, p. 623. Value of all commodities owned, in million dollars.
[e] *Agricultural Statistics, 1972,* table 682, p. 562. Farm income in millions of dollars, aggregate basis.
[f] Aggregate government farm payments divided by total cash receipts times 100.
[g] *Agricultural Statistics, 1972,* table 755, p. 637 (in million acres).
[h] Prior to 1949: *Agricultural Statistics, 1960,* table 632, p. 441 (base 1910–14 = 100). Beginning 1949: *Agricultural Statistics, 1972,* table 677, p. 553 (base 1967 = 100).
[i] 1964–1971: Balance of payment, liquidity basis—*Statistical Abstract, 1972,* Table 1267, p. 764.

the development process. One way of interpreting the data is as follows. Government stocks increased very substantially from 1952 through 1955 (Table 1). In a sense an attempt was being made to offset the consequences of the over-valuation of the dollar. The government was in effect substituting for the foreign market and preserving the relatively elastic demand curve which the foreign market would have sustained. This action was possible because of the remaining power of the agricultural bloc.

However, this policy could not be sustained. The obvious, overt costs of the program made it unacceptable. The political power of the urban vote was growing, and it seems clear that they realized that with prevailing policies they were not sharing in the benefits of technical change, represented by the burgeoning stockpiles in government hands to which they did not have access. As a result, support prices were gradually flexed downward in real terms, contributing to the persistent decline in the parity

Table 2. Agricultural commodity support prices, real terms,[a] 1949–1972

| | Corn | Cotton[b] | Peanuts | Wheat | Tobacco[c] | Butter-fat | Milk for Manu-facture | Wool | Sorghum |
|---|---|---|---|---|---|---|---|---|---|
| | $/bu. | $/lb. | $/lb. | $/bu. | $/lb. | $/lb. | $/cwt. | $/lb. | $/cwt. |
| 1949 | 1.38 | .2675 | .103 | 1.92 | .418 | .575 | 3.08 | .416 | 2.05 |
| 1950 | 1.43 | .2714 | .105 | 1.94 | .438 | .584 | 2.99 | .440 | 1.82 |
| 1951 | 1.41 | .2744 | .104 | 1.96 | .457 | .609 | 3.24 | .457 | 1.96 |
| 1952 | 1.41 | .2723 | .106 | 1.94 | .446 | .610 | 3.39 | .478 | 2.10 |
| 1953 | 1.40 | .2692 | .104 | 1.93 | .418 | .588 | 3.27 | .464 | 2.12 |
| 1954 | 1.41 | .2751 | .106 | 1.95 | .417 | .490 | 2.74 | .463 | 1.99 |
| 1955 | 1.38 | .2769 | .107 | 1.82 | .422 | .491 | 2.75 | .542 | 1.55 |
| 1956 | 1.29 | .2525 | .098 | 1.72 | .421 | .504 | 2.80 | .534 | 1.70 |
| 1957 | 1.16 | .2397 | .092 | 1.66 | .423 | .488 | 2.70 | .516 | 1.55 |
| 1958 | 1.10 | .2529 | .086 | 1.47 | .442 | .458 | 2.48 | .502 | 1.48 |
| 1959 | .90 | .2440 | .078 | 1.45 | .445 | .454 | 2.46 | .498 | 1.22 |
| 1960 | .84 | .2290 | .080 | 1.41 | .439 | .447 | 2.42 | .490 | 1.20 |
| 1961 | .94 | .2585 | .087 | 1.40 | .434 | .473 | 2.66 | .485 | 1.51 |
| 1962 | .93 | .2513 | .086 | 1.55 | .434 | .443 | 2.41 | .480 | 1.49 |
| 1963 | .96 | .2482 | .086 | 1.55* | .433 | .444 | 2.40 | .474 | 1.53 |
| 1964 | .94 | .2528 | .085 | 1.35* | .432 | .438 | 2.38 | .468 | 1.51 |
| 1965 | .93 | .2474 | .083 | 1.28* | .428 | .441 | 2.40 | .460 | 1.48 |
| 1966 | .94 | .2195 | .082 | 1.37* | .424 | .491 | 2.89 | .469 | 1.48 |
| 1967 | .95 | .2229 | .080 | 1.30* | .420 | .477 | 2.81 | .463 | 1.50 |
| 1968 | .91 | .2186 | .081 | 1.23* | .415 | .444 | 2.88 | .451 | 1.45 |
| 1969 | .86 | .2234 | .079 | 1.24* | .407 | .438 | 2.73 | .441 | 1.37 |
| 1970 | .81 | .2235 | .077 | 1.21* | .402 | .431 | 2.81 | .434 | 1.29 |
| 1971 | .78 | .1994 | .078 | 1.09* | .401 | — | 2.85 | .416 | 1.30 |
| 1972 | .76 | .1931 | .078 | — | .407 | — | 2.76 | .403 | 1.38 |

Sources: *Agricultural Statistics, 1967,* Table 685; *Agricultural Statistics 1972,* Table 675; and nominal price of wheat from 1963 to present, designated with an asterisk, from *Agricultural Statistics, 1972,* Table 16.

[a] Deflated by consumer price index, 1947–49 = 100.

[b] American upland.

[c] Flue-cured, types 11–14.

ratio (Table 1).[10] In effect domestic agricultural prices were allowed to drift downwards to the levels established from international markets through the over-valued exchange rate.

Agriculture was not abandoned, however. Rather, the form in which the assistance was provided changed. While real agricultural product prices were permitted to drift downward, land was taken out of production, first in an acreage reserve and later, more extensively, in the conservation reserve, the feed grain program, and other land retirement programs (Table 1). Income losses that would have occurred in the market place were made up by land diversion payments. The artificial scarcity of land bid up its price, which gave capital gains to land owners. In a very real sense the political process found a way of dividing the benefits of technical change between the consumers and the land owners.

There are other aspects of the policy mix that are worth noting. Under the urban-oriented Kennedy government, the stocks in government hands were used in further income redistribution programs, in the form of school lunches and the food stamp program. In addition, the stocks were used as an integral element of our foreign aid program—for good and/or bad. Export subsidies paid from the treasury kept exports from declining as much as they might have otherwise and in essence delayed the day of reckoning from the over-valuation of the dollar.

## Agricultural development

A number of paradoxes are apparent in the above picture. The first is that agricultural output continued to grow in the face of persistent

[10] The parity ratio has been criticized for over-stating the decline in relative farm prices, since it includes wage rates, taxes, and interest in the denominator. A ratio formed by dividing the index of prices received by farmers by the index of prices paid for items used in production has a temporal pattern very similar to that of the parity ratio, but declines by only 18 percent from 1952 through 1971, compared to 30 percent for the parity ratio.

downward pressures in real agricultural prices. The second is that agricultural exports through commercial channels did grow through the post-war period, even though the dollar appears to have become increasingly more over-valued—which should have priced agricultural products increasingly out of the market, other things being equal.

This development process can be interpreted with a combination of Figures 1 and 2. First, assume that when the dollar began to be over-valued, the agricultural sector was at something corresponding to point 1 in Figure 2. As a result of the gradual over-valuation of the dollar, the unit price line would decline to something like $A'B'$. If $IPC_{t+1}$ were not available, output would decline since profits would become negative for the marginal firms in the industry, and they would leave or go out of production. More generally, mobile resources would leave the industry, and the return to fixed factors would decline. If a country were exporting in the initial situation, it would export less as a result of over-valuation (Fig. 1) and, depending on relative magnitudes, might even begin to import. If it were initially in a position of importing, it would import even more.[11]

In the case of the U. S., however, this was not the situation. Because of the sizeable investments in basic and applied research, not only was a new *IPC* available, but the applied research capacity was available to attain it. With declining profits serving as a powerful inducer of innovative activity at the farm level, and the public and private agricultural research stations turning out a steady flow of new production technology to be adopted, there was ample incentive and means to move toward point 2 on Figure 2. As the curves are drawn, this in itself would involve a shift away from land-intensive factor proportions and toward the use of a larger proportion of land-augmenting capital.

In the context of Figure 1, the shift to point 2 would correspond to a shift to the right of the product supply curve. Hence, the quantity available for exports need not necessarily decline, even though the domestic price is declining. However, viewed externally, the over-valuation of the dollar corresponds to a rise in the price of these products. Foreign markets may well disappear even though the technical efficiency of production is increasing. In this sense the country would fail to capitalize on its technical progress as a source of exchange earnings and instead would channel the benefits of technical change to the domestic consumer in the form of lower agricultural prices.

Alternatively, the shift in the supply curve may be of such a magnitude that exports increase even at the lower domestic price. (This would depend on the elasticity of the demand and supply curves and the magnitude of the shift in the supply curve.) This appears to be what happened in the case of the U. S. As a result, producers were able to reap some of the benefits from the technical change, even though an important share of them was being channeled to the consumer by means of exchange policy.

On this interpretation the effect of the price support program was to cushion the effect of the over-valuation. Relative farm prices continued to decline through the 1950's and 1960's (see data on parity ratio Table 1), but probably not by as much or as rapidly as they otherwise might have. In order to bring supply in adjustment with demand, the government turned to various land retirement schemes. The consequence of this set of policies was to make land artificially scarce and to offset further the negative consequences of the over-valuation of the dollar by providing capital gains to existing land holders.[12]

This increase in land values in turn very likely caused further technical change. As shown in Figure 2, the effect of the increase in land values was to shift the unit price line to something like *CD*. This induces innovation and the search for new production technology along a given *IPC* and results in the shift from a position like point 2 to point 3, with a shift in factor proportions from II to III. This represents the adoption of land-augmenting technologies and results in an increase in yields per acre. (This tendency was further stimulated by the autonomous decline in real fertilizer prices.)

In this process a number of other things happen. First, the price of land is bid up by adopters able to purchase land from those unable or unwilling to innovate, for the land is

[11] This situation where a new *IPC* is not available characterizes many low-income countries. It explains why over-valuation tends to have such a deleterious effect on agriculture in such countries, and why a number of them slip from being net exporters to being net importers of agricultural products under such circumstances.

[12] In a sense this was the substitution of a capital gain induced by artificial scarcity for the one that would have been realized from technical change if the dollar had not been over-valued.

worth more to them than to the non-innovator. This in effect expels the non-innovator from the agricultural sector, thereby speeding up the rate of out-migration. An interesting aspect of the process is that the migrant is benefited with a capital gain that he realized only by selling and presumably leaving the industry. Ruttan [9] has noted that a considerable amount of capital has been transferred from the farm to the non-farm sector through this labor market phenomenon. It is worth noting that the capital gain also provides a means of sustaining the farmer and his family while they move and adjust to new employment. Hence, the land market subsidizes migration, and the need for direct government support of the migration process is reduced, at least for previous owners of land. This appears to be an advantage to expelling the labor force through this means.[13]

It should be noted that land is not the only resource that is valorized in the process, however. To the extent that entrepreneurial or innovational skills are in inelastic supply, the owner of these skills also receives an economic rent. Although this rent is not capitalized in the human agent because anti-slavery laws preclude the buying and selling of people, the price of labor services rendered by owners of this scarce talent rises. This provides an incentive to mechanization,[14] which may be further motivated by an increase in the land owned by the entrepreneur. It is for this reason that the non-innovator who sells his land tends to be expelled from the sector rather than to remain as an employee of the innovator. Moreover, the mechanization that is so induced probably adds further pressures in the land market, while at the same time imposing further adjustment on the landless worker.

### The labor market and adjustment

If resources were perfectly mobile, there need not be an income problem in agriculture as a result of the over-valuation of the exchange rate. Rather, resources would flow out of the industry until equilibrium was reestablished at the lower relative price, and the agricultural sector would be smaller than it otherwise would have been.

But resources are not perfectly mobile. In the present case the combination of rapid technical change induced by the price decline and domestic fiscal and monetary policies used to combat the balance of payments problem complicated the problem in a substantial way—at least during the 1950's. Land is a relatively fixed resource for U. S. agriculture, even though marginal adjustments do take place. The adoption of new production technologies, many of which were imbedded in physical capital, increased the return to capital and thereby induced more of this resource into the industry. Therefore, the agricultural labor force had to bear the burden of the adjustment process.

Research on the agricultural labor market has shown that the ratio of prices received by farmers to the prices they pay for inputs other than labor is an important shifter of the demand for labor [10, 13, 16]. To the extent that trade policy contributed to the decline in this ratio over time, incentives were provided to shift labor out of agriculture.[15] This author has shown elsewhere [12] that the coefficient of this relative price variable in the reduced form for the hired agricultural labor market is .18 for employment and .36 for agricultural wages. Hence, a decline in the "parity ratio" would lead to a reduction in employment and a decline in returns to labor, other things being equal. Moreover, the effect of a given decline in the price relative is larger on the return to labor than on the level of employment, at least in the short run—a reflection of the relative inelasticity of the supply curve of agricultural labor.

Hence the incentives provided by the shift in the terms of trade were in the direction of transferring labor out of agriculture—with an income-depressing effect being one of the consequences of the shift in the price relative and the relatively inelastic supply curve for labor. But it was here that the various elements of our policy came into conflict during the late 1950's. The policy response to the decline in our gold

[13] The same process would occur if the increase in land values were induced by the land market treadmill that results from capitalizing Schumpeterian profits. In either case the process benefits only the previous owners of land. The adjustment process of the landless worker is not facilitated, and for this reason this group has borne the major share of the agricultural adjustment burden.

[14] The substitution process between labor and $K_L$ can be analyzed with the aid of Figure 2. All that is needed is to re-label the axes; the analysis is the same. Rising wage rates in the non-farm labor market become an important factor affecting the agricultural wage, however, (see [12]) as well as the rate at which labor is transferred out of agriculture.

[15] The decline in product price was not the only factor inducing the shift of labor out of agriculture. Non-farm wages were rising and previous studies [12, 16] have shown this to be a strong factor affecting out-migration.

stock and persistent balance of payments problem was an over-riding concern with domestic inflation. Monetary and fiscal policies were kept relatively tight throughout the 1950's, with the result that the level of unemployment was high and gradually increasing over time.

It has been demonstrated that out-migration from agriculture is quite sensitive to the level of unemployment in the general economy [4, 10, 12, 14, 16, 17]. Persistently high levels of unemployment experienced during the 1950's therefore impeded the outflow of labor from the agricultural sector. Hence the policy mix that evolved—an over-valued exchange rate and the relatively high levels of unemployment which it induced through the response of domestic policy to the gold outflow and balance of payments problems—was very much of a "double squeeze" on agriculture, particularly on the labor force. Price relatives were changing so as to stimulate an increased outflow of labor, while the slack in aggregate demand and the higher levels of unemployment which it caused impeded that outflow.

Two comments are pertinent to set this analysis in perspective. First, the set of domestic price support policies that were implemented during the decade of the 1950's can be interpreted as at least a partial attempt to restore or counterbalance the decline in terms of trade that was being imposed by the over-valuation of the dollar. Second, it seems clear that they did not completely offset it and that their effect, combined with the slack in aggregate economic activity, did not completely shut off the outflow of labor from agriculture. The out-migration was sizeable throughout the 1950's. But the important point is that it would have been even higher, other things being equal, had the rate of unemployment been down around 4 percent and the price support programs not in effect.

### Towards domestic equilibrium in the 1960's

The artificial scarcity of land created by the land retirement programs could have been self-perpetuating. Adoption of land-substituting, output-increasing innovations that it induced could have led to further increases in output, thereby calling for more land retirement, and so on. But a number of forces were working against this. First, the real value of support levels, especially for land-intensive crops such as corn and wheat, was permitted to erode as the general price level rose. In addition and perhaps more importantly, the labor force was making a longer-term adjustment. The economic boom of the 1960's, when the level of unemployment declined to 4 percent and below, facilitated the out-migration. Opportunities for jobs and rising wages in the non-farm sector made non-innovators more willing to leave agriculture. With this adjustment the pressures for bidding up land values were probably dampened, and in turn this inducement to the further adaption of output-increasing technologies was lessened.

By 1970–1971 the U. S. was about as close to begin in adjustment *at prevailing domestic price ratios* as it had been for 20 years—or at the peak of the Korean War. Support levels had been worked down to near-equilibrium levels with a couple of important exceptions. Stocks in government hands had been worked down, with acreage diversion fluctuating from year to year but not trending upward. And the labor market was nearer to equilibrium, with the gap between farm and non-farm income having been reduced substantially.

This is not to imply, however, that the U. S. was anywhere near a *socially* optimum use of its resources, especially if international opportunity costs are considered. To the contrary, the dollar became increasingly over-valued towards the latter part of the 1960's, culminating in the high balance of payments deficit of 1971. The extent to which this country was at a less than socially optimum position can be seen by analyzing the nature of the new situation that has resulted from two successive devaluations by the U. S. and the general realignment of currencies that has resulted.

## Changed Conditions for U. S. Agriculture

The combined effect of the U. S. devaluations and the currency realignments has been to place considerable upward pressure on the price of tradeable products (exports and imports)—viewed domestically. Although the devaluation itself does not immediately change the nominal value of exportable products, it sets forces into play which lead to a bidding up of their prices. This can be seen most easily by recognizing that under the new currency alignments a given unit of the currency of a foreign country is worth more in terms of dollars. This can be viewed either as an upward shift of the demand curve for U. S agricultural products in terms of dollars, or as a decline in the price of the same goods in terms of the foreign currency.

After complete adjustment it would not nec-

essarily be the case that average prices for agricultural products in the aggregate would rise by the amount of the devaluation, since not all products are traded or tradeable. By the same token, however, it should be recognized that the largest shift in exchange ratios was between Japan and the U. S. and that Japan is an important purchaser of U. S. agricultural output. In addition, the devaluation also makes imports more expensive domestically. Agricultural imports, especially those competing with U. S. products, have been growing over time. The increased price for these products will make domestic suppliers more competitive, thereby bidding more resources into these sectors. To the extent that the prices of these products rise, there will be a shift in demand towards substitute products. Hence the effect of the devaluation will tend to spread throughout the sector, with higher feed grain prices, for example, raising the cost structure of the livestock sector.

One aspect of the new situation is that an important basis of the massive disequilibrium in world agriculture that Hayami and Ruttan [5] have referred to has been eliminated. Resources in U. S. agriculture will be more nearly valued at their world opportunity cost levels, and the U. S. will be closer to realizing its true comparative advantage and capitalizing, from a trade standpoint, on the sizeable investments in science and technology that it has made in the past.

On the domestic scene, however, the situation is not so sanguine. The consequence of the realignment of currency values will likely be a redistribution of income, at least in the short and into the intermediate run. The terms of trade have shifted in favor of agriculture, which means that food prices are increasing in relative terms. Given that prices in the non-farm sector are rigid downward, this rise in agricultural prices has caused a spurt in inflation. It is somewhat surprising that it is not recognized the extent to which this was partly due to the devaluation—especially in light of its magnitude. Such inflationary spurts due to devaluation are well recognized in developing countries and are one of the main reasons such countries are unwilling to devalue until all else fails.

The rise in relative food prices represents a decline in real income for consumers, other things being equal. Moreover, the decline in real income will be distributed regressively, with low income groups suffering relatively larger income losses than the more well to do. In addition, those with fixed sources of income will also suffer relatively.

There is also likely to be a sizeable transfer of income from the consumer to the owners of agricultural resources, with the magnitude of the transfer depending on what is done about payments under current programs and the extent to which they have in the past compensated the effects of the over-valuation. In the short term land values are likely to increase rapidly.

What happens over the longer term will depend on the policy response of the government and on resource mobility. Should there be a return to new pegged exchange rates under conditions of realignment, and U. S. inflation should outrun that in her trading partners, this country could become over-valued again. A return to rigidly pegged exchange rates does not appear likely, however. Alternatively, the government might be more disposed to set quotas on the export of food products—a not uncommon feature of developing countries [11, 15]. The effect again would be to intervene in the distribution of income between producers and consumers.

Finally, if exchange rates remain flexible and export quotas are not imposed (except as short-term correctives), the consequences over the longer term will depend on the mobility of resources. If the long run supply curve for agricultural output is perfectly elastic, agricultural prices will eventually decline from their short-term elevated levels, although it should be noted that the supply curve has probably shifted upward as a result of increases in the prices of tradeable inputs such as fertilizers and the feed-grains themselves. On the other hand, if there is a rising supply price for agricultural output associated with inducing additional resources into agriculture, this country could experience a "permanent" rise in the relative price of agricultural products, and the day of the U. S. consumer spending only 16 percent of his budget on food will be a thing of the past. In my judgment it is the latter that we are likely to experience, at least in the foreseeable future.

## Some Concluding Comments

The basic premise of this paper has been that the exchange rate has been an important omitted variable in past interpretations of U. S. agricultural development and trade problems.[16] Moreover, it has been argued that the exchange rate

[16] For an example of such omission in an otherwise excellent analysis of world agriculture, see [7].

has been an important variable affecting the rate at which new production technology has been adopted, as well as an important factor affecting how the benefits of technical change have been distributed between the U. S. producer and the U. S. consumer, and ultimately between the U. S. economy and the world at large.[17] If this interpretation is correct, an important share of the rise in agricultural prices in mid-1973 is a result of monetary phenomena which induced an export boom in an economy that was already responding to expansive monetary policies, and in the case of agriculture, increased the foreign demand for U. S. output at the same time that this demand was already rising from temporarily bad weather conditions in other countries and a temporary decline in the Peruvian fishmeal industry.

To put the analysis in perspective, it is recognized that agricultural prices in the early 1950's were high by most historical standards and that their secular decline through the rest of that decade and the next cannot be ascribed solely to the over-valuation of the dollar, that trade restrictions as well as the exchange rate affected U. S. foreign markets, and that economic development in general exerted major influences on the agricultural sector. Hence, the burden of the paper is not to argue that the over-valuation of the dollar was the only factor causing the farm problem, nor that the recent devaluations have been responsible for all recent increases in agricultural prices. Rather, the contention here is that the exchange rate has had an important role in both phenomena which has for the most part been ignored, and that, moreover, an adequate understanding of the performance of the agricultural sector cannot be had without a more ample consideration of the exchange rate.

Both space and time limitations have precluded a systematic parametric analysis of the agricultural sector in the present paper, although the author hopes to have such results in the near future. However, an important characteristic of the analysis is that it has implications or predictions that are confirmable by future events. If the present interpretation is correct, the following events should transpire after devaluation, unless government measures are taken to off-set them:[18] (1) the parity or a comparable price-relative ratio should rise; (2) land values should increase at a more rapid rate than they have in the past; (3) the fraction of consumer expenditures spent on food should rise; and (4) there should be a shift in the product mix of U. S. agriculture toward export products. Needless to say, some of these events are already taking place.

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[17] Unless offsetting measures are taken by countries which import U. S. agricultural products, incomes in those countries will be redistributed away from the landowners in those countries and toward their consumers.

[18] The return of land previously held out of production will undoubtedly help cushion the adjustment process. It cannot be expected, however, to alter the implications in a substantial way over the longer run.

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# An Investigation of the Importance of Risk in Farmers' Decisions*

Richard E. Just

**This paper presents an empirical investigation of the importance of risk in decisions. The adaptive expectations geometric lag model is generalized by geometrically including quadratic lag terms indicative of risk. The computation of consistent estimators is described, and the model is applied in the analysis of California field-crop supply response. Results indicate that the effects of stabilization (possibly associated with government programs) might have seriously offset the acreage-reducing effects of voluntary acreage restrictions. Finally, more general implications relating to reduced-form estimation of the standard Nerlovian model are discussed.**

*Key words:* quadratic lag; risk; supply response; adaptive expectations; Nerlovian model.

Although economists (see, e.g., [1, 6]) generally acknowledge the importance of price, yield, and income variability in farmers' production decisions, few econometric studies include risk variables in the analysis of agricultural supply response. Yet a quantitative knowledge of farmers' reactions to changing risk is of considerable importance in evaluating alternative government programs and policies directed towards stabilization of prices and incomes. While an effort has been made to determine the importance of risk in some studies (see, e.g., [4]), only very arbitrary procedures have generally been employed.[1] This paper presents a more general method of evaluating farmers' response to changing risk. Although a fairly rigorous justification of the model (under certain assumptions) can be found in [8], only a simple motivation will be given here so results of the empirical application can be described more fully.[2]

## Motivation

A model often used in empirical work is

$$(1)\quad Y_t = A_0 + A_1\theta \sum_{k=0}^{\infty} (1-\theta)^k Z_{t-k-1} + \epsilon$$

where $Y_t$ is a $p \times 1$ vector variable for which explanation is sought; $Z_t$ is an $n \times 1$ vector variable including such explanatory forces as prices; $A_0$ is a $p \times 1$ parameter vector; $A_1$ is a $p \times n$ parameter matrix; $\theta$ is a scalar parameter; and $\epsilon_t$ is a $p \times 1$ stochastic disturbance vector.[3] In the adaptive expectations interpretation of this model, where

$$Z^* = \theta \sum_{k=0}^{\infty} (1-\theta)^k Z_{t-k-1},$$

$Z^*_t$ is regarded as the decision makers' subjective expectations vector for the (mean of) prices and yields on which the decisions in $Y_t$ are based. Consider a similar way of including decision makers' subjective evaluation of the variance of prices and yields. If

$$[Z_{i,t} - Z^*_{i,t}]^2 = \left[Z_{i,t} - \theta \sum_{k=0}^{\infty} (1-\theta)^k Z_{i,t-k-1}\right]^2$$

is regarded as an observation on risk (or variance) where

$$Z_t = \begin{bmatrix} Z_{1,t} \\ \cdot \\ \cdot \\ Z_{n,t} \end{bmatrix} \qquad Z^*_t = \begin{bmatrix} Z^*_{1,t} \\ \cdot \\ \cdot \\ Z^*_{n,t} \end{bmatrix},$$

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[1] For example, Behrman [4] and others use a fixed-length moving average of squared deviations about a simple moving average of the same length as measurements of subjective risk for the associated economic variables of interest.

[2] The assumptions used in [8] are basically that the economic environment is a Markovian stochastic process in which the true state cannot be observed without error; the distribution of both the environmental state and noise in the observed state is multivariate normal with decision makers holding Wishart-normal subjective distributions on the associated parameters; and the risk or variance associated with the environmental state changes slowly relative to other elements in the model.

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[3] The model in (1) is then simply a multivariate version of the adaptive expectations model used by Cagan [5].

then decision makers might form expectations for risk by geometrically weighting past observations on risk similar to the way in which expectations for the mean are formed. Where $\phi$ is a scalar geometric parameter, $W^*_t$ is an $n \times 1$ vector with $i$th coordinate[4]

$$W^*_{i,t} = \phi \sum_{k=0}^{\infty} (1-\phi)^k [Z_{i,t-k-1} - Z^*_{i,t-k-1}]^2,$$

and $A_2$ is a $p \times n$ parameter matrix, the model in (1) might be generalized by including risk as follows:

$$(2) \qquad Y_t = A_0 + A_1 Z^*_t + A_2 W^*_t + \epsilon_t.$$

In case the decision makers' subjective evaluation of covariance were also thought to be of importance, $W^*_t$ might be extended to include geometric weightings of past observations on covariances. Treating

$$\psi_{i,j,t} = [Z_{i,t} - Z^*_{i,t}][Z_{j,t} - Z^*_{j,t}]$$

as an observation on the covariance of the $i$th and $j$th prices or yields, the following might be defined

$$W^*_t = \phi \sum_{k=0}^{\infty} (1-\phi)^k \psi_{t-k-1}$$

where

$$\psi_t = \begin{bmatrix} \psi_{1,1,t} \\ \cdot \\ \cdot \\ \cdot \\ \psi_{1,n,t} \\ \psi_{2,2,t} \\ \cdot \\ \cdot \\ \cdot \\ \psi_{2,n,t} \\ \psi_{3,3,t} \\ \cdot \\ \cdot \\ \cdot \\ \psi_{n-2,n,t} \\ \psi_{n-1,n-1,t} \\ \psi_{n-1,n,t} \\ \psi_{n,n,t} \end{bmatrix}.$$

[4] One need not assume that the geometric parameters used in forming subjective means and variances are equal. Indeed, the theoretical development in [8] indicates that they may be different. However, since subjective variances are formed by geometrically weighting squared deviations about subjective means, $W^*_t$ depends on both geometric parameters.

One might then consider the model

$$(3) \qquad Y_t = A_0 + A_1 Z^*_t + A_2 W^*_t + \epsilon_t$$
$$= A_0 + A_1 \theta \sum_{k=0}^{\infty} (1-\theta)^k Z_{t-k-1} + A_2 \phi \sum_{k=0}^{\infty} (1-\phi)^k \psi_{t-k-1} + \epsilon_t$$

where $A_2$ is some $p \times k$ parameter matrix $[k = n(n+1)/2]$. This generalization of the adaptive expectations model could thus possibly allow the explanation of diversification as well as risk aversion since both subjective variances and covariances are included.

## A Possible Method of Estimation

Although the model in (3) appears quite complex for estimation purposes, several methods of estimation (depending on data availability and dimensions) have been worked out in [8]. The method used to obtain the empirical results in this paper basically depends on the availability of historical $Z_t$ data which can be used in approximating $\psi_t$.

Suppose each of the variables in (3) is divided into observable and unobservable parts similar to the approach taken by Klein [10]. That is, suppose (3) is rewritten as

$$Y_t = A_0 + A_1 Z^*_{t_0} (1-\theta)^{t-t_0} + A_1 \Big[\theta \sum_{k=0}^{t-t_0-1} (1-\theta)^k Z_{t-k-1}\Big] + A_2 W^*_{t_0} (1-\phi)^{t-t_0} + A_2 \Big[\phi \sum_{k=0}^{t-t_0-1} (1-\phi)^k \psi_{t-k-1}\Big] + \epsilon_t$$
$$= \beta_0 + \beta_1 X_{1,t}(\theta) + \beta_2 X_{2,t}(\theta) + \beta_3 X_{3,t}(\phi) + \beta_4 X_{4,t}(\theta,\phi,Z^*_{t_0}) + \epsilon_t$$

where

$$(4) \qquad \beta_0 = A_0$$
$$\beta_1 = \theta \sum_{k=t-t_0}^{\infty} (1-\theta)^{k-t+t_0} A_1 Z_{t-k-1} = A_1 Z^*_{t_0}$$
$$\beta_2 = A_1$$
$$\beta_3 = \phi \sum_{k=t-t_0}^{\infty} (1-\phi)^{k-t+t_0} A_2 \psi_{t-k-1}$$

$$= A_2 W^*_{t_o}$$

$$\beta_4 = A_2$$

$$X_0 = 1$$

$$X_{1,t}(\theta) = (1-\theta)^{t-t_o}$$

$$X_{2,t}(\theta) = \theta \sum_{k=0}^{t-t_o-1} (1-\theta)^k Z_{t-k-1}$$

$$X_{3,t}(\phi) = (1-\phi)^{t-t_o}$$

$$X_{4,t}(\theta,\phi,Z^*_{t_o}) = \phi \sum_{k=0}^{t-t_o-1} (1-\phi)^k \psi_{t-k-1}.$$

All $\psi_t$ vectors and thus $X_{4,t}$ are written as dependent on $\theta$ and $Z^*_{t_o}$ as well as the observed $Z_t$ for $t \geqq t_o$ since the general form of the coordinates of $\psi_t$ can be expressed as

$$\left[Z_{i,t} - \theta \sum_{k=0}^{t-t_o-2} (1-\theta)^k Z_{i,t-k-2} - (1-\theta)^{t-t_o-1} Z^*_{i,t_o}\right] \times \left[Z_{j,t} - \theta \sum_{k=0}^{t-t_o-2} (1-\theta)^k Z_{j,t-k-2} - (1-\theta)^{t-t_o-1} Z^*_{j,t_o}\right].$$

If the data available on $Y_t$ and $Z_t$ are for time periods $t_o$ through $t_f$, then $\beta_1$ and $\beta_3$ will be fixed throughout the sampling period and can therefore be treated as parameters to be estimated since they are indeed unknown. The model in (3) might then be rewritten in a more familiar form as

$$Y_t = \beta X_t + \epsilon_t \text{ for } t = t_o, \ldots, t_f$$

where

$$\beta = [\beta_0 \beta_1 \beta_2 \beta_3 \beta_4]$$

and

$$X_t = X_t(\theta,\phi,Z^*_{t_o}) = \begin{bmatrix} X_0 \\ X_{1,t}(\theta) \\ X_{2,t}(\theta) \\ X_{3,t}(\phi) \\ X_{4,t}(\theta,\phi,Z^*_{t_o}) \end{bmatrix}.$$

Thus, when $\theta$, $\phi$, and $Z^*t_o$ are known, there is simply a classical multivariate regression problem. Assuming the $\epsilon_t$ are distributed identically and independently with a normal distribution having zero mean vector and covariance matrix $\Sigma$, i.e.,

$$\epsilon_t \sim iid\, N(O,\Sigma),$$

the log of the likelihood function for the estimation problem is

$$L(\beta,\Sigma|\theta,\phi,Z^*t_o,Y_t,Z_t) = -\frac{Tp}{2}\log(2\pi) - \frac{T}{2}\log|\Sigma^{-1}| - \frac{1}{2}\sum_{t=t_o}^{t_f}(Y_t - \beta X_t)'\Sigma^{-1}(Y_t - \beta X_t).$$

Conditional maximum likelihood estimates of $\beta$ and $\Sigma$ given $\theta$, $\phi$, and $Z^*_{t_o}$ are then (see, e.g., Anderson [2] or Rao [11])

(5) $$\hat{\beta}(\theta,\phi,Z^*_{t_o}) = YX'(XX')^{-1}$$

$$\hat{\Sigma}(\theta,\phi,Z^*_{t_o}) = -\frac{1}{T}\sum_{t=t_o}^{t_f} (Y_t - \hat{\beta}X_t)(Y_t - \hat{\beta}X_t)'$$

where

$$X = [X_{t_o} \ldots X_{t_f}]$$

and

$$Y = [Y_{t_o} \ldots Y_{t_f}].$$

Since both $\theta$ and $\phi$ can be constrained to lie in small intervals for all practical purposes, search techniques can also be employed to locate the maximum likelihood estimates of $\theta$ and $\phi$ given $Z^*_{t_o}$ Typically, the geometric terms, $(1-\theta)$ and $(1-\phi)$, are constrained to lie in the open interval $(-1,1)$ to insure the existence of $Z^*_t$ and $W^*_t$ in (3). Under certain additional assumptions, the parameters $\theta$ and $\phi$ in this model can be further constrained to lie in the positive unit interval $(0,1)$.[5] Hence, by picking

[5] Assuming the state of the economic environment is positively related to the state in the immediately preceding time period, decision makers' optimal $\theta$ and $\phi$ would lie in the unit interval. Such would be the case in a stochastic Markovian environment where the expected direction of change is zero (see Just [8]). Hence, certain kinds of cyclic or systematic economic environments may be excluded by assuming $\theta$ and $\phi$ are positive, but obviously all the methods presented here would carry through if one only assumed $|\theta| < 1$ and $|\phi| < 1$. The more restrictive assumptions were used here since casual observation of the data revealed no significant cyclical

a sufficient number of points $\theta_i$ and $\phi_i$ such that $0 < \theta_i < 1$ and $0 < \phi_i < 1$ (possibly according to some search procedure), the likelihood function can be maximized over $\theta$ and $\phi$ as follows:

$$L\{\hat{\beta}(\hat{\theta},\hat{\phi},Z^*_{t_o}),\hat{\Sigma}(\hat{\theta},\hat{\phi},Z^*_{t_o}),\hat{\theta},\hat{\phi}|Z^*_{t_o},Y_t,Z_t\} = \max_{\substack{\theta_i\epsilon(0,1)\\ \phi_i\epsilon(0,1)}} L\{\hat{\beta}(\theta_i,\phi_i,Z^*_{t_o}),\hat{\Sigma}(\theta_i,\phi_i,Z^*_{t_o}), \theta_i,\phi_i|Z_{t_o},Y_t,Z_t\}.$$

Thus, all that is needed is an estimator for $Z^*_{t_o}$. If historical data are available for $Z_t$ prior to $t_o$, say for $t_h \leqq t < t_o$, then $Z^*_{t_o}$ might be estimated on that basis. That is, where

$$Z^*_{t_o} = \theta \sum_{k=0}^{\infty} (1-\theta)^k Z_{t_o-k-1},$$

$Z^*_{t_o}$ might be estimated as

$$s_{t_o}(\theta) = c(t_o - t_h)\, \theta \sum_{k=0}^{t_o-t_h} (1-\theta)^k Z_{t_o-k-1} \tag{6}$$

where $c(t_o - t_h)$ is chosen to give a normalized total weighting to the $Z_t$ for $t_h \leqq t < t_o$, for example,[6]

$$c(t_o - t_h) = \left[\theta \sum_{k=0}^{t_o-t_h} (1-\theta)^k\right]^{-1}. \tag{7}$$

Hence, $s_{t_o}(\theta)$ will be a consistent estimator of $Z^*_{t_o}$ even when a consistent estimator of $\theta$ is substituted in (6) if $T = t_f - t_h + 1 \rightarrow \infty$ in such a way that both $T_1 = t_o - t_h \rightarrow \infty$ and $T_2 = t_f - t_o + 1 \rightarrow \infty$.

The complete estimation method would then be summarized by (5), (6), (7), and

$$L\{\hat{\beta}(\hat{\theta},\hat{\phi},s_{t_o}),\hat{\Sigma}(\hat{\theta},\hat{\phi},s_{t_o}),\hat{\theta},\hat{\phi},s_{t_o}|Y_t,Z_t\} = \max_{\substack{\theta_i\epsilon(0,1)\\ \phi_i\epsilon(0,1)}} L\{\hat{\beta}[\theta_i,\phi_i,s_{t_o}(\theta_i)],\hat{\Sigma}[\theta_i,\phi_i,s_{t_o}(\theta_i)], \theta_i,\phi_i,s_{t_o}(\theta_i)|Y_t,Z_t\}.$$

For each point $(\theta_i,\phi_i)$, $s_{t_o}(\theta_i)$ is computed and substituted for $Z^*_{t_o}$ in $X_{4t}$. Estimates of $\beta$ and $\Sigma$ associated with $(\theta_i,\phi_i)$ are then computed and the likelihood function evaluated. The $\theta_i$, $\phi_i$, $s_{t_o}(\theta_i)$, $\hat{\beta}[\theta_i,\phi_i,s_{t_o}(\theta_i)]$, and $\hat{\Sigma}[\theta_i,\phi_i,s_{t_o}(\theta_i)]$ associated with the maximum likelihood point are then taken as estimates of $\theta$, $\phi$, $Z^*_{t_o}$, $\beta$, and $\Sigma$, respectively. As shown in [8], the resulting estimators are consistent for the respective parameters as is generally the case with maximum likelihood estimators when $X$ is nonstochastic and $\theta \neq \phi$.[7] When $\theta = \phi$, consistency is maintained for $\hat{\beta}_0$, $\hat{\beta}_2$, and $\hat{\beta}_4$ as well as for $\hat{\theta}$, $\hat{\phi}$, and $s_{t_o}$, but $\hat{\beta}_1$ and $\hat{\beta}_3$ become unidentifiable since $X_{1,t}$ becomes identically equal to $X_{3,t}$. If $\Sigma = \sigma^2 I$, for some scalar $\sigma^2$, then $\hat{\beta}$ is also asymptotically efficient.[8]

## An Application of the Risk Model to the Analysis of Acreage Response for Some California Field Crops

In a study of the California field crop industry [8], the estimation technique described above has been employed in the analysis of acreage response for eight field crops in six exhaustive districts of the state. The estimated model in each case basically corresponds to the model in (3) with some additional variables included to capture the effects of government programs.[9] Although space prevents reporting the results for all cases here, some exemplary

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response and since the less restrictive assumptions would have made the likelihood search area under H2 four times larger.

[6] Of course,

$$\lim_{t_h \rightarrow -\infty} s_{t_o}(\theta) = Z^*_{t_o}$$

for all $c(t_o - t_h)$ such that

$$\lim_{t_h \rightarrow -\infty} c(t_o - t_h) = 1.$$

However, $c(t_o - t_h)$ is chosen here in an obvious way to provide a better estimate of $Z^*_{t_o}$ in a small sample situation. Actually, for all practical purposes, $s_{t_o}(\theta)$ can be made essentially equal to $Z^*_{t_o}$ without a great deal of historical data when $\theta$ is not close to zero since computer round-off error prevents the effect of observations far in the past.

[7] Note that the requirement that $X$ be nonstochastic does not exclude the assumptions related to risk that are used here. All that is required is that $s_t$ be observed without error. If either the decision maker or the econometric investigator observes $s_t$ with error, then the standard errors-in-the-variables problem is encountered. Although the latter case probably more nearly characterizes the empirical problem addressed later in this paper, the errors in observation are likely very small compared to disturbances in the decision equation in (3) so that inconsistency is negligible. See Theil [12] for related arguments.

[8] Several variations of this estimation method which obtain asymptotic efficiency when $\Sigma \neq \sigma^2 I$ are discussed in Just [8].

[9] For a detailed discussion of the government program component of this model, see Just [9].

findings are given. Some common difficulties are then discussed and the general results and implications appraised.

Since acreages planted were not always available in appropriate detail for the purposes of the analysis, the $Y_t$ vector is composed of the acreages harvested of the important field crops. Unfortunately, good input cost data were also not available. The cost data that were available indicated little or no variation during the period of investigation. Furthermore, it appears that many input costs are known with certainty at the time of decision making (planting time) so that they have no effect on risk.[10] Hence, the explanatory variables used in this application exclude costs and depend only on prices and yields. Also, since the set of competing crops in California is so large, the price and yield variables were combined for each crop forming returns variables. Hence, the $Z_t$ vector is a vector of prices times yields corresponding to the acreage variable $Y_t$. Nothing in the model, however, prevents the separate inclusion of prices and yields and their associated variabilities and covariabilities. Such an approach should indeed be a useful direction in future research with this model.

Three hypotheses are given particular attention in the following empirical investigation:

H1. Decisions are not significantly affected by subjective variances or covariances,
H2. decisions are not significantly affected by the subjective covariances, and
H3. the temporal lag distributions for the subjective mean and variance are equal, i.e., $\theta = \phi$.

Accordingly, four variants of the model given in (3) are used in the acreage response investigation. Under Model 1 corresponding to H1 above, $\beta_3$ and $\beta_4$ are constrained to be zero. Hence, $\phi$ drops out of Model 1, and only a one dimensional likelihood search on $\theta$ is required. Model 1 is essentially, then, just a standard multivariate geometric lag model. Under Model 2 corresponding to H2 above, only the elements of $\beta_4$ corresponding to subjective covariances in $X_{4,t}$ are constrained to be zero. Hence, a two-dimensional likelihood search is used directly. Under Model 3 corresponding to H3 above, the constraint $\theta = \phi$ was imposed. Model 3 is investigated in this study for two reasons. First, it seems intuitively plausible that decision makers may well weight past observed phenomena equally in forming both kinds of subjective knowledge. The second and more important reason is that estimation is highly simplified when $\theta = \phi$. If sufficient evidence is found supporting H3, then perhaps some future studies might be able to develop results where risk is important (H1 is false) without relying on the cumbersome two dimensional search method required under H2. Although this model was investigated both with and without covariances, results are only reported for the cases when covariances do not enter. Additionally, however, since $\theta = \phi$ or $(1-\theta)^{t-t_0} = (1-\phi)^{t-t_0}$ results in multicollinearity, $X_{3,t}(\phi)$ is also excluded from Model 3. Hence, the estimated $\beta_1$ is actually an estimate of $\beta_1 + \beta_3$ under the hypothesis of Model 3. Again, only a one-dimensional likelihood search is required. Finally under Model 4, the model in (3) is estimated without constraints.

Exemplary results of estimation for Models 1, 2, and 3 are reported in Tables 1 through 4 for two crops, wheat and grain sorghum, in two exhaustive districts of the California central valley. Variables in the reported equations are defined as follows:[11]

$Y_1$ = Wheat acreage in the San Joaquin Valley
$Y_2$ = Grain sorghum acreage in the San Joaquin Valley
$Y_3$ = Wheat acreage in the Sacramento Valley
$Y_4$ = Grain sorghum acreage in the Sacramento Valley
$X_1$ = Proportion of wheat program compliance (acreage-wise)
$X_2$ = Wheat allotment on participating farms
$X_3$ = Wheat price support level multiplied by $X_1$
$X_4$ = $(1-\theta)^{t-t_0}$ [corresponding to $X_{1,t}(\theta)$ in (4)]
$X_5$ = Subjective mean of returns for wheat [corresponding to $X_{2,t}(\theta)$ in (4)]
$X_6$ = $(1-\phi)^{t-t_0}$ [corresponding to $X_{3,t}(\phi)$ in (4)]
$X_7$ = Subjective variance of returns for

[10] Admittedly, additional variables may still be needed to reflect the effects of dramatic technological changes before they are transmitted through the usual geometric lag framework. But again, the effects of some kinds of technology (machinery, etc.) will be known at the time of decision making so that risk factors will be affected relatively little.

[11] Although defined generally, the independent variables used in each case pertained only to the district for which the dependent variable is defined.

Table 1. Wheat acreage in the San Joaquin Valley

| Model | Estimated Equation | Results Given the *MLE*'s $\theta$ | $\phi$ | $R^2$ | $\overline{R^2}$ | $D$ |
|---|---|---|---|---|---|---|
| 1 | $Y_1 = -1{,}369{,}612 - 48{,}847.4X_1 + .257915X_2 + 46{,}389.4X_3$ | .059 | | .77 | .70 | 1.08 |
| | (534,412) (41,661.3) (.240158) (21,042.0) | | | | | |
| | $+ 1{,}453{,}022X_4 + 30{,}941.0X_5$ | | | | | |
| | (516,951) (10,983.6) | | | | | |
| 2 | $Y_1 = -122{,}581 - 36{,}157.4X_1 + .200994X_2 + 38{,}489.8X_3$ | .070 | .003 | .89 | .83 | 1.95 |
| | (4,100,214) (36,942.2) (.186306) (18,305.6) | | | | | |
| | $+ 2{,}409{,}732X_4 + 56{,}237.4X_5 - 2{,}170{,}666X_6 - 50{,}269.2X_7$ | | | | | |
| | (1,030,607) (31,294.1) (3,184,882) (27,735.0) | | | | | |
| 3 | $Y_1 = -3{,}602{,}852 - 31{,}830.8X_1 + .170560X_2 + 14{,}694.2X_3$ | .035 | .035 | .87 | .82 | 1.74 |
| | (764,017) (37,037.4) (.186681) (17,384.0) | | | | | |
| | $+ 3{,}769{,}377X_4 + 90{,}732.2X_5 - 3{,}117.75X_7$ | | | | | |
| | (770,960) (18,110.9) (899.54) | | | | | |

wheat [corresponding to $X_{4,t}(\theta,\phi, Z^*_{t_0})$ in (4)]

$X_8$ = Indicator of years when cotton allotments were imposed

$X_9$ = Cotton allotment

$X_{10}$ = Cotton price support level

$X_{11}$ = Estimated proportion of participation by corn and grain sorghum producers in the feed grains program

$X_{12}$ = Grain sorghum price support level multiplied by $X_{11}$

$X_{13}$ = Subjective mean of returns for grain sorghum

$X_{14}$ = Subjective mean of returns for barley

$X_{15}$ = Subjective variance of returns for grain sorghum

$X_{16}$ = Subjective variance of returns for barley.

Table 2. Grain sorghum acreage in the San Joaquin Valley

| Model | Estimated Equation | Results Given the *MLE*'s $\theta$ | $\phi$ | $R^2$ | $\overline{R^2}$ | $D$ |
|---|---|---|---|---|---|---|
| 1 | $Y_2 = -82{,}601.1 + 59{,}640.4X_4 + 73{,}057.5X_8 - .056114X_9$ | .071 | | .96 | .94 | 3.00 |
| | (211,045) (202,494) (37,418.9) (.051647) | | | | | |
| | $- 234.540X_{10} - 31{,}879.7X_{11} + 31{,}705.0X_{12} + 3{,}805.76X_{13}$ | | | | | |
| | (128,148) (18,226.9) (12,342.2) (2,617.1) | | | | | |
| 2 | $Y_2 = -187{,}719 + 224{,}845X_4 - 74{,}070.1X_6 + 93{,}480.9X_8$ | .240 | .290 | .97 | .95 | 3.23 |
| | (148,818) (269,093) (259,913) (44,638.6) | | | | | |
| | $- .069244X_9 - 407{,}797X_{10} - 30{,}076.0X_{11} + 43{,}463.1X_{12}$ | | | | | |
| | (.059757) (217.901) (19,797.1) (17,184.1) | | | | | |
| | $+ 4{,}469.20X_{13} - 296.617X_{15}$ | | | | | |
| | (1,578.06) (120.247) | | | | | |
| 3 | $Y_2 = -180{,}806 + 139{,}924X_4 + 96{,}334.5X_8 - .071962X_9$ | .241 | .241 | .97 | .96 | 3.25 |
| | (140,240) (123,369) (43,207.6) (.057925) | | | | | |
| | $- 407.533X_{10} - 34{,}172.8X_{11} + 46{,}329.9X_{12} + 4{,}454.67X_{13}$ | | | | | |
| | (177.277) (19,562.2) (15,689.5) (1,499.60) | | | | | |
| | $- 372.204X_{15}$ | | | | | |
| | (142.610) | | | | | |

Table 3. Wheat acreage in the Sacramento Valley

| Model | Estimated Equation | Results Given the *MLE*'s $\theta$ | $\phi$ | $R^2$ | $\overline{R}^2$ | $D$ |
|---|---|---|---|---|---|---|
| 1 | $Y_3 = 4{,}782{,}900 - 167{,}511X_1 + 1.08876X_2 - 4{,}676{,}694X_4$<br>(2,716,017) (28,775) (.24211) (2,722,534)<br>$- 67{,}481.8X_5$<br>(41,594.3) | .006 | | .73 | .67 | 1.11 |
| 2 | $Y_3 = -4{,}521{,}675 - 138{,}406X_1 + .918546X_2 + 4{,}645{,}512X_4$<br>(1,626,242) (22,803) (.186388) (1,632,206)<br>$+ 92{,}434.2X_5 - 2193.36X_7$<br>(29,643.6) (553.51) | .020 | .020 | .86 | .82 | 2.30 |
| 3 | Since the results under Model 2 satisfy the restrictions of Model 3, the same results were obtained under Model 3. | | | | | |

The time intervals covered by the study are defined by

$$t_o = 1949$$
$$t_f = 1970$$
$$t_h = 1941.$$

Results are not reported for Model 4 since subjective covariances appeared to play no significant role for any of the crops. Hypothesis H2 was thus accepted in the case of the California field crops.

Although the model in (3) suggests an identical $\theta$ and $\phi$ for all of the crops that might be included in $Y_t$, such a constraint was not imposed in estimation since the group of farmers which determines an average $\theta$ and $\phi$ for one crop is not necessarily the same as for another. The model in (3) was then estimated separately for each crop in each district under each of the hypotheses.[12]

The search procedures employed in locating $\hat{\theta}$ and $\hat{\phi}$ were as follows. For the models requiring only a one-dimensional search on the unit interval, the conditionally maximized likelihood function was evaluated by means of a standard regression program for $\theta = 0.1, 0.2, \ldots, 0.9$. In all cases the likelihood function appeared to

[12] See [8] for a discussion of the possible aggregation bias resulting from unequal $\theta$'s and $\phi$'s over decision makers.

Table 4. Grain sorghum acreage in the Sacramento Valley

| Model | Estimated Equation | Results Given the *MLE*'s $\theta$ | $\phi$ | $R^2$ | $\overline{R}^2$ | $D$ |
|---|---|---|---|---|---|---|
| 1 | $Y_4 = 53{,}792.7 - 15{,}749.2X_4 - 49{,}630.9X_{11} + 8{,}189.95X_{13}$<br>(99,967.2) (104,935) (14,530.4) (2,661.44)<br>$- 12{,}497.1X_{14}$<br>(3,569.8) | .088 | | .91 | .89 | 2.26 |
| 2 | $Y_4 = -81{,}528.7 + 153{,}974X_4 - 37{,}392.8X_6 - 32{,}009.6X_{11}$<br>(60,674.5) (132,027) (83,665.5) (15,103.5)<br>$+ 4{,}741.86X_{13} - 4{,}290.60X_{14} - 183.201X_{15} + 204.532X_{16}$<br>(1,395.26) (1,740.87) (63.486) (132.149) | .260 | .390 | .93 | .89 | 2.36 |
| 3 | $Y_4 = -44{,}261.6 + 79{,}457.1X_4 - 37{,}405.1X_{11} + 4{,}134.69X_{13}$<br>(39,870.1) (42,972.3) (14,972.3) (887.56)<br>$- 3{,}889.21X_{14} - 234.374X_{15} + 217.574X_{16}$<br>(1,409.14) (65.405) (167.220) | .276 | .276 | .93 | .90 | 2.36 |

behave smoothly although an occasional likelihood function with two local maxima was found. In every case the nine-point plots appeared to indicate concavity in the neighborhood of the local maxima except when $\hat{\theta}$ was near zero or one. Hence, a Fibonacci search was invoked from each of the indicated local maxima.[13] In each case, a sufficient number of points were evaluated so as to locate the maximum likelihood estimate of $\theta$ with an accuracy of 0.006 under the assumption of local concavity. The globally maximizing $\theta$ was then chosen as the maximum likelihood estimate. Although in a few cases the likelihood function appeared to continue to increase as $\theta$ approached zero or one, an evaluation of the likelihood function in the limit indicated the maximum likelihood estimates were in the interior of the unit interval. One-dimensional likelihood functions (maximized at each point with respect to all the other coefficients) typical of those found by Model 1 are given in Figures 1 and 3. An ordinal representation of the likelihood functions found by Model 3 is evident in Figures 2 and 4.

For the models requiring a two-dimensional search in the unit square, the conditionally maximized likelihood function was evaluated for all combinations of $\theta = 0.1, 0.3, \ldots, 0.9$ and $\phi = 0.1, 0.3, \ldots, 0.9$. Again, the likelihood function appeared to behave smoothly, but two local maxima were indicated in many cases due to the multicollinearity caused by the two variables $(1-\theta)^{t-t_0}$ and $(1-\phi)^{t-t_0}$. According to the regression routine employed, one of the above variables was dropped from the calculations as the two variables approached collinearity along the line $\theta = \phi$ to maintain nonsingularity in the estimation of other coefficients. Hence, a trough often resulted along the line $\theta = \phi$ as the "explanation" associated with the additional variable was lost. In cases where the global maximum fell close to the trough, a local maximum was usually found on the opposite side. In each case an additional pattern search method was carried through from each of the local maxima indicated by the coarse grid search. Although the details of the method will not be discussed here, the method was essentially a steepest ascent procedure with some modifications designed to take advantage of the diagonal ridges found on each side of the trough. Barring unusual circumstances, the method was constructed so as to locate the maximum likelihood estimates of $\theta$ and $\phi$ to an accuracy of 0.01. Again, the globally maximizing $\theta$ and $\phi$ were chosen as the maximum likelihood estimates. Likelihood contours typical of those found by Model 2 are given in Figures 2 and 4.[14]

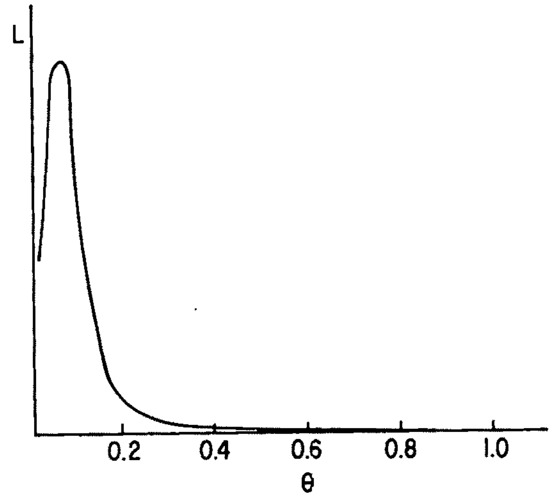


**Figure 1. Likelihood function found by Model 1 for grain sorghum in the San Joaquin Valley**

A plot of the maximizing values of $\theta$ and $\phi$ for all the equations estimated by Model 2 in [8] is given in Figure 5. Although the concentration of points just off the diagonal ($\theta = \phi$) caused by the trough is apparent, a tendency towards the diagonal is also evident as all but five or six of the points appear as though held away from the diagonal only by the coincidence of multicollinearity as $\theta \to \phi$. Furthermore, three of the outlying points account for much smaller acreages than any of the remaining points. After their removal, at least 14 of the remaining 17 points appear close to the diagonal. Thus, results tended also to favor hypothesis H3.

## Appraisal of the Results

In general, the performance of the generalized model described in this paper in the analysis of California field crop acreage response could be considered quite good. Results are particularly encouraging for crops and districts in which production was large. Well over 90 percent of the

[13] The well known Fibonacci search method is the optimal one-dimensional search method in the sense that it minimizes the maximum possible interval of uncertainty in which the maximum of a unimodal function can lie after a fixed number of points on the function have been evaluated. For a detailed discussion of the method see Aoki [3] or Howard [7].

[14] Of course, the contours are only approximate as only a finite number of points on the likelihood functions have actually been evaluated.

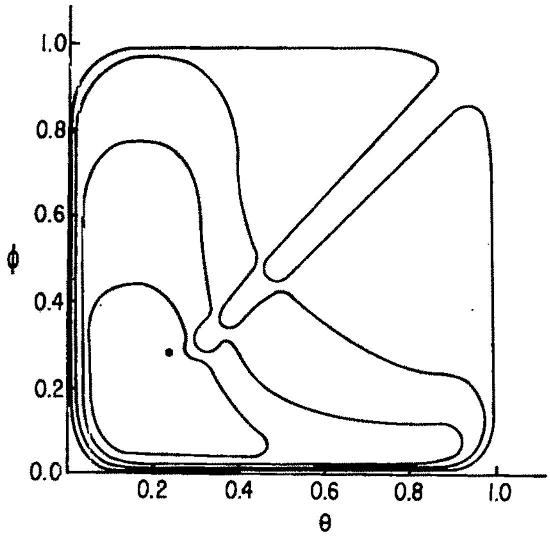


Figure 2. Likelihood contours found by Model 2 for grain sorghum in the San Joaquin Valley

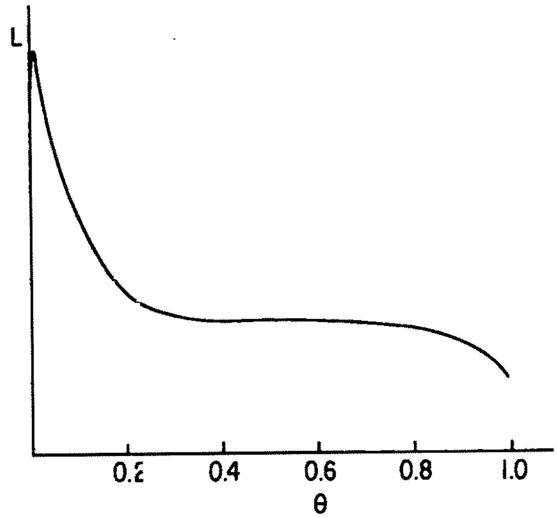


Figure 3. Likelihood function found by Model 1 for wheat in the Sacramento Valley

acreage variation in the San Joaquin Valley, the most important district, is explained when risk variables are included in the analysis. The poorest results are generally obtained for crops that are least important in the district in question.

In many cases, however, particularly those for which government programs are less important, the standard multivariate Nerlovian model (corresponding to Model 1) failed to capture adequately one of the most important forces operative in acreage response. The more general model often indicated risk to be quite significant in acreage response.[15] In some cases (of which wheat in the Sacramento Valley was one), only Models 2 and 3, which include risk, gave any reasonable results.

In general, the only equations in which risk did not appear significant pertained to crops strongly regulated by government programs. Hence, the results suggested that hypothesis H1 as pertaining to all field crops should be rejected. For cotton and rice, the most strictly regulated crops included in the study, risk could not be shown to be of importance. Although wheat has also been regulated rather strictly during the last two decades, the restrictions have not been of the same relative importance in the California central valley where many more profitable cropping alternatives exist. Hence, risk becomes of importance in the wheat equations reported in this paper. In some mountainous regions of California where wheat is an important crop, however, the effects of changing risk were insignificant just as for cotton and rice in the central valley.

Although in the case of the grain sorghum equations reported in this paper the fit does not appear to improve greatly with the inclusion of risk, the subjective risk variables still are of indicated significance (for a given $\hat{\theta}$ and $\hat{\phi}$).

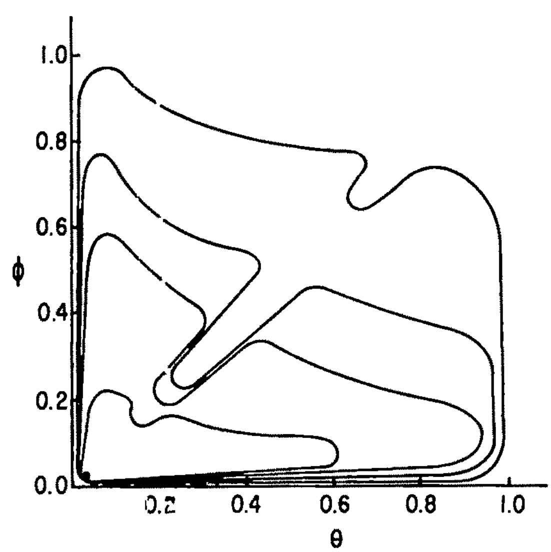


Figure 4. Likelihood contours found by Model 2 for wheat in the Sacramento Valley

[15] Although the standard errors reported in Tables 1 through 4 are conditional on $\theta$ and $\phi$, they apply unconditionally in an asymptotic sense because $\theta$ and $\phi$ are estimated consistently. Thus, a discussion of the significance of results is possible although somewhat less confidence may be placed in the conclusions.

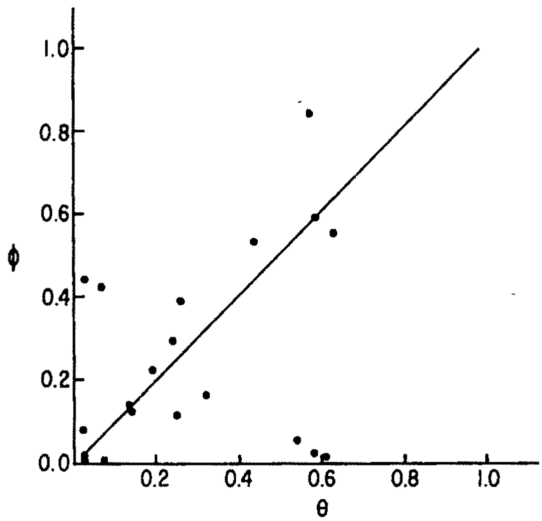


Figure 5. Likelihood maximizing points found for the reported equations estimated by Model 2

Since the level of returns for grain sorghum has increased so rapidly with the introduction of hybrid seed, the subjective mean variables are much more important and, hence, most of the explanation is obtained with Model 1.

## Implications Related to Government Programs

Since one of the major goals of the government farm programs is stabilization of farm prices and income, the estimated parameters, $\theta$ and $\phi$, are of particular interest since they allow the estimation of farmers' subjective variance both before and after the implementation of restricting programs. On the basis of the $\hat{\theta}$ and $\hat{\phi}$ for each equation estimated under Model 2 and the data used in estimation (including the historical data), farmers' subjective mean and variance estimates are reported in Table 5 for both 1953 and 1970. Years 1953 and 1970 are chosen specifically for the purposes of demonstrating the possible (but not conclusive) effects of government farm programs.[16] Prior to 1953, few restrictions were placed on farmers through government programs but the years leading up to 1970 saw many such restrictive programs directed at stabilization.

Evidently, the feed grains program has been quite successful in achieving stability for grain sorghum returns (similar results have also been found for barley and corn in [8]). Reductions in subjective variance are substantial in both districts according to Table 5. Subjective variances have not fallen nearly so dramatically for wheat. The high subjective variance for wheat, however, is apparently a result of the discontinuation of marketing quotas in 1964. Prices dropped dramatically as a result of the substantial increase in national production and, although voluntary allotments continued, prices have been somewhat unstable since.

### Possible offsetting effects

Finally, one must consider the comparative effects of the restrictive controls and the stabilization which is supposedly achieved by the controls. Consider, for example, the feed grain program where voluntary allotments have been imposed. Since estimated participation in 1970 in the San Joaquin Valley was 44.44 percent (and zero in 1953), the estimated reduction in acreage due directly to the voluntary allotments is $.444 \times 30{,}076 = 13{,}367$ acres (see the co-

[16] Since no corresponding demand study has been completed, the observed stabilization entering the calculations for Table 5 cannot necessarily be attributed to the government programs.

Table 5. Estimated subjective mean and variance of farmers before and after the implementation of restricting programs

| | | 1953 | | 1970 | | Acreage Change Attributable to Directly Pertaining | |
|---|---|---|---|---|---|---|---|
| District | Crop | Mean | Variance | Mean | Variance | Allotment | Sub. Variance |
| San Joaquin Valley | Wheat | 34.07 | 122.55 | 44.14 | 121.66 | −18,867 | 44,740 |
| | Grain Sorghum | 60.75 | 134.58 | 83.33 | 60.84 | −13,367 | 21,873 |
| Sacramento Valley | Wheat | 41.48 | 211.02 | 48.19 | 237.99 | −80,957 | −59,155 |
| | Grain Sorghum | 77.49 | 274.15 | 94.41 | 58.38 | −10,503 | 39,529 |

efficient of $X_{11}$ in Table 2, Model 2). But as indicated in Table 5, grain sorghum producers' subjective variance has decreased by 134.58 − 60.84 = 73.74. Hence, acreage expansion due to stabilization (possibly attributable to government programs) is estimated as 73.74 × 296.617 = 21,873 acres (see the coefficient of $X_{15}$ in Table 2, Model 2). If all observed stabilization were due to government programs, the net effect on acreage would then be positive rather than negative. Similar results are also obtained for grain sorghum in the Sacramento Valley and wheat in the San Joaquin Valley (as well as for barley and corn in many areas of California). Of course, an adequate analysis of demand must be undertaken before the cause of the observed stabilization can be determined. These results are only meant to indicate possibilities for future research. Obviously, the important possibilities indicated by the above preliminary results have serious implications with the present increased tendency away from strict controls and toward voluntary kinds of programs.

## Implications Related to Nerlovian Model Estimation

Even more general implications might be drawn from the results. In point of fact, the widely used Nerlovian model,

$$Y_t = A_0 + A_1\Big[\theta\sum_{k=0}^{\infty}(1-\theta)^k Z_{t-k-1}\Big] + \epsilon_t,$$

has been commonly estimated in its reduced form,

$$(8)\quad Y_t = (1-\theta)Y_{t-1} + \theta A_0 + \theta A_1 Z_{t-1} + \nu_t$$

where

$$\nu_t = \epsilon_t - (1-\theta)\epsilon_{t-1}.$$

In an adaptive expectations context, the term $(1-\theta)Y_{t-1}$ is then thought to carry only information relating to the subjective mean of the distribution of $Z_t$. However, if Models 2 or 3 are actually operative, that term may carry far more information. Consider the corresponding case under Model 3 where $\phi = \theta$ and

$$Y_t = A_0 + A_1\Big[\theta\sum_{k=0}^{\infty}(1-\theta)^k Z_{t-k-1}\Big] + A_2\Big\{\theta\sum_{k=0}^{\infty}(1-\theta)^k\Big[Z_{t-k-1} - \theta\sum_{k=0}^{\infty}(1-\theta)^j Z_{t-k-j-2}\Big]^2\Big\} + \epsilon_t$$

with $Z_t$ now assumed scalar for ease of exposition. Similarly, the corresponding reduced form would be found as

$$(9)\quad Y_t = (1-\theta)Y_{t-1} + \theta A_0 + \theta A_1 Z_{t-1} + A_2\Big[Z_{t-1} - \theta\sum_{j=0}^{\infty}(1-\theta)^j Z_{t-j-2}\Big]^2 + \nu_t.$$

Now the term $(1-\theta)Y_{t-1}$ additionally carries some of the effects of the variation in subjective risk. Moreover, when $\theta$ is close to zero as it seemed to be in many cases in this study, almost all the effects of changing subjective risk may enter through the term $(1-\theta)Y_{t-1}$. Hence, one might be able to obtain results that appear to be quite satisfactory by estimating the standard Nerlovian model in its reduced form when in actuality, much of the real explanation is lost with the exclusion of risk.

Furthermore, tests based on the Durbin-Watson statistic or spectral analysis might lead one to conclude erroneously that the partial adjustment model is operative when in fact the adaptive expectations mechanism is of importance. As is evident from (8), when the term

$$A_2\Big[Z_{t-1} - \theta\sum_{j=0}^{\infty}(1-\theta)^j Z_{t-j-2}\Big]^2$$

is not highly correlated with other variables in the model, the estimated disturbance would actually be estimating

$$(10)\quad \nu^*_t = \theta A_2\Big[Z_{t-1} - \theta\sum_{j=0}^{\infty}(1-\theta)^j Z_{t-j-2}\Big]^2 + \nu_t - c_\nu$$
$$= \theta A_2\Big[Z_{t-1} - \theta\sum_{j=0}^{\infty}(1-\theta)^j Z_{t-j-2}\Big]^2 + \epsilon_t - (1-\theta)\epsilon_{t-1} - c_\nu$$

if a Nerlovian model in its reduced-form were estimated when risk is actually important [where $c_\nu$ is the expected value of the first term in (10) during the period of estimation]. If the variation in the first term dominates that of $\nu_t$, then the disturbance process could more closely resemble white noise. Under the common stochastic

assumptions, the theoretical disturbance process in a Nerlovian partial adjustment model is white noise while in an adaptive expectations model, the disturbances are $\nu_t = \epsilon_t - (1 - \theta)\epsilon_{t-1}$ where the $\{\epsilon_t\}$ process is white noise. The $\nu_t$ process, of course, does not resemble white noise when $(1 - \theta)$ is not close to zero. If one were then to use the Durbin-Watson statistic or even spectral analysis to test against the presence of an adaptive expectations mechanism, the associated statistical power could easily be near zero in cases where risk is important.

Although the presence of some government programs has prevented the simplified estimation of complete reduced form equations such as (8) and (9), some preliminary results have indicated that in cases where risk is apparently important, good fit is often obtained with the reduced form of the standard Nerlovian model; fit usually deteriorates when the structural form of the Nerlovian model is estimated; and fit once again improves when risk variables are added to the structural form. These results should then lead one to exercise caution in interpreting reduced-form estimation results for the standard Nerlovian model.

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# Guaranteed Price Adjustment and Market Stability in the United Kingdom: The Case of Beef and Milk*

MARTIN EVANS

**The dynamic properties of a producer-government interaction model are investigated to show why the United Kingdom's policy of regulating its agricultural markets by annually adjusting guaranteed prices failed to control persistent fluctuations in supplies, market prices, and subsidy costs of beef and milk during the fifties and sixties. The evidence suggests that governments' responses to undesired movements, particularly in potential milk supplies, were excessive in terms of the magnitudes and frequency of official price adjustments. This emphasized the cyclical tendencies in the beef-milk economy, which was also susceptible to the destabilizing effects of random milk yield variation.**

*Key words:* **price policy; market stability; quantitative; U. K.**

A BASIC PRINCIPLE of post-war economic policy in the United Kingdom was that the quantity and composition of agricultural output should be mainly controlled by changes in the farm gate price of individual commodities. From 1947 onwards, government regularly reappraised the levels of fixed or guaranteed agricultural prices at the Annual Review and Determination of Guarantees, and this periodic resetting of official prices became the dominating regulator of the agricultural economy. In 1954 free markets in agricultural products reappeared, and from this date most producer prices were then supported by deficiency payments, which were subsidies on unit output representing a substantial part of any shortfall between the average market price and the ruling guaranteed price. This method of economic "steering" was applied without substantial modification until very recently, so it is surprising how little is known about the way it worked. The efficacy of regulating agricultural markets by annually adjusting guaranteed prices has been the subject of much general speculation but of little empirical analysis. Now that the U. K. is replacing this method of farm price support and stabilization by the Common Market system based on import levies, thus shifting the burden of subsidy from the taxpayer to the consumer, it seems an appropriate time to consider how the original government-producer interaction process appears to have functioned. What can be learned about agricultural price-fixing under the old policies may be of help in devising new ones.

The commodities selected for study are beef and milk. Control over developments in the beef-milk sector has preoccupied successive U. K. agricultural administrations due to its prime importance in total farm output, the great annual variation in the cost of supporting producer prices, and the large quantity of beef imported. Four main policy objectives were relevant to the fixing of guaranteed prices for beef and milk, two specifically concerned with cattle production, two representing important goals for agriculture in general:

(1) maintaining desired trends in home-produced beef and milk supplies;
(2) minimizing fluctuations about trend in market prices for beef;
(3) maintaining desired trends in aggregate farm income and in the income of certain disadvantaged groups of farmers;
(4) ensuring an equitable allocation of national income between the farm and the non-farm population in the long-run.

The last two objectives were largely achieved: total net farm income has maintained an upward trend since 1954, and the cost of supporting beef and milk prices has followed a downward trend. However, the guaranteed price system failed demonstrably with regard to the first two objectives: home beef supplies were not considered adequate at any time while milk was in surplus supply from 1954 until about 1963.[1] Efforts to stabilize the beef and milk markets were not very successful either. Annual movements in beef production become more violent after the introduction of deficiency payments than in the

* The author is indebted to Mr. G. B. Aneuryn Evans of the Faculty of Economics, Cambridge University, who wrote the computer programs used in this study.

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[1] After this time milk supply matched demand to a more satisfactory extent, and government now accepted that encouraging the dairy herd to produce more beef would inevitably increase milk output as well.

preceding 15 years, with the cyclical pattern of growth in cattle numbers continuing as before causing large fluctuations in market prices for beef and in the cost of subsidizing final producer prices. This was a major disappointment because it was originally hoped that the guaranteed price/deficiency payments scheme would go a long way towards stabilizing fatstock markets.

Beef and milk price support costs reached a peak in the 1961–62 guarantee year, and in 1964 the government admitted that the rising level and unpredictability of these costs had been influencing the determination of guarantees at recent Annual Reviews [8]. Thus the failure of a policy instrument in one area, supply control, was affecting its proper use in another, namely price support. It is the purpose of this paper to try to throw some light on the relationship between government intervention in the U. K. beef and milk markets and their stability.

## Method

The approach is based on period analysis of linear models. Foote was among the first to apply this method of economic dynamics to an agricultural situation, reducing his model of the U. S. feed-livestock economy to an eighth-order difference equation [4]. Other examples of the same approach are Reutlinger's study of the U. S. beef market [14] and Jones's analysis of the pig cycle in the U. K. [9]. The U. K. beef-milk sector is a particularly interesting case for dynamic analysis because, unlike the systems just referred to, it consists of two separate markets for technically interrelated products. Since the greater proportion of home-fed beef supplies comes from the dairy herd, output levels of beef and milk are closely related in the short run.

An econometric model of beef and milk supply response to price is first estimated, the policy instruments of interest—guaranteed prices for beef and milk—being specified as exogenous variables. Further equations are then added, describing how government adjusts guaranteed price levels in order to stabilize supply about some desired trend and to support producer prices, so that in this expanded model, guaranteed prices become endogenous variables. These extra equations are not estimated econometrically for reasons given below. The final system thus consists of a model of producer response to price (including government-fixed prices) combined with models of government's reactions to this response, expressed as further price adjustments.

The final system is reduced to a set of non-stochastic homogeneous difference equations with constant coefficients.[2] The time path of any endogenous variable in such a system is determined by the stimulus causing the response, the initial conditions, and the system's characteristic equation which provides the "inherent" dynamic features of the system, and on which attention is focused here. The solution to the characteristic equation is of the form

$$(1)\quad x(t) = \sum_{i}^{m} e_i(Z_i)^t + \sum_{i}^{n} (D_i)^t (f_i \cos tR_i + g_i \sin tR_i)$$

where

$x(t)$ is the value of the system at time $t$,

$Z_i$ is the $i$th real root,

$(D_i)^t$ $(\cos tR_i + \sin tR_i)$ is the trigonometric form of the $i$th complex root $c \pm di$, $i$ being an imaginary number, and

$e$, $f$ and $g$ are constants to be determined in accordance with the initial conditions.

The dynamic implications (degree of stability and cyclic periodicity) of the solutions to systems containing different government behavior equations should reveal the type of price policy which maintains the kind of instability observed in the milk and beef markets (and which might therefore represent a reasonable model of actual government behavior) and the types of price policy which increase or decrease market stability compared with the historic situation.

## A Model of Beef and Milk Supply Response to Price

The important structural relations of the U. K. beef-milk economy at the primary market level[3] form a system in which annually observed current endogenous variables are related either to endogenous variables in previous time periods (dynamic structuring) or to other current endogenous variables on which they themselves exert no influence (recursive structuring).

The mechanism linking changes in guaranteed prices for beef and milk to changes in output

[2] A good account of this method of analysis is given in Gandolfo [6].

[3] This level would include fat cattle sales and liquid milk deliveries to the Milk Marketing Boards.

of these products consists of four basic processes:

(1) The response of potential output from a level of productive capacity fixed in the short run. For young beef supplies (steer and heifer slaughterings) this manifests itself as the proportion of calves born which are retained for rearing,[4] and for milk, as variation in supply due to average yield changes.
(2) The response of the level of productive capacity as represented by the cow inventory. Changes in cow numbers shift the short-run supply schedules for beef and milk through time.
(3) The effect on current beef output of changes in productive capacity. An increase in cow numbers will normally mean an increased demand for heifers for breeding, which reduces heifer beef supplies and vice versa.
(4) The influence of changes in beef and milk supplies on the effective "free" market prices for these products.

Seven equations were specified to represent the processes above and were estimated from annual observations for the period 1954–68 by ordinary least-squares regression.[5] Variables are as follows: ($c$) denotes an endogenous variable which is currently determined only; ($p$) is a predetermined endogenous variable; and ($x$) is an exogenous variable.

| | | |
|---|---|---|
| $MKSL$ | ($c$) | is total annual sales of milk ex-farm (million gallons), |
| $CH$ | ($p$) | is total cow herd (cows in calf or in milk) at December (000's head), |
| $T$ | ($x$) | is a trend term, |
| $PRM$ | ($p$) | is average annual producer price for milk (pence per gallon), |
| $GPM$ or $GPB$ | ($x$) | is average annual guaranteed price for milk (pence per gallon) or beef (shillings per live cwt.), |
| $SQ$ | ($x$) | is annual standard quantity for milk (million gallons), |
| $M$ or $F$ | ($p$) | is inventory of male or female calves (less than 1 year old) at December (000's head), |
| $P'$ | | is average annual producer price for clean fat cattle (see below), |
| $FP$ | ($x$) | is average annual price of cattle compound feed (index, 1954/55–56/57 = 100), |
| $MPB$ | ($p$) | is average annual market price of beef (index 1954/55–56/57 = 100), |
| $S$ | ($c$) | is annual total of home-fed steer and clean heifer slaughterings (000's head), |
| $IMPF$ | ($x$) | is annual total of steers and heifers imported as fatstock from the Irish Republic and slaughtered in the U. K., i.e., foreign-fed slaughterings (000's head), and |
| $Y$ | ($x$) | is national disposable income (million £ sterling). |

Some notes on the price variables may be helpful here.

### Beef prices

The final price producers receive per live weight of young beef is made up of the market price they obtained themselves and a government deficiency payment based on the difference between the prevailing guaranteed price for beef ($GPB$) and the average market price ($MPB$). It has been demonstrated elsewhere [2, 10] that separate effects of the market and guaranteed prices for beef can be distinguished. There are good reasons for this: the guaranteed price announced for each year indicates to producers government's current plans for beef production; thus large increases give producers confidence about prospects for the next few years and vice versa. On the other hand, the actual price received by farmers at the market also has a strong psychological effect on their outlook. Low market prices cause anxiety about government's willingness to go on paying out high price support bills indefinitely. The market price is also the basis on which cow-beef is sold, this not being eligible for deficiency payment. In the empirical model, therefore, both $MPB$ and $GPB$ were used together in place of $P'$.

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[4] In the U. K., most unwanted calves are slaughtered for veal soon after birth.

[5] The possibility of contemporaneous error correlation in the recursive subsystem was admitted, and a modified TSLS estimation procedure (described by Harlow [7] and Fox [5]) was applied. Coefficients differed little from the OLS estimates in most cases, but in others the statistical rejection of certain price parameters resulted in some very unlikely supply elasticities. The OLS results were therefore used.

**Milk prices**

There is no price corresponding to a "free" market price in the case of milk, since any government subsidy is paid to Milk Marketing Boards which make a single payment to producers for unit output *viz.* variable *PRM*. Producers do not therefore receive an additional deficiency payment on unit output as in the case of beef.

**Feed prices**

The relatively closed livestock economy of the U. S. means that feed prices may be specified as endogenous variables in models of the system. In the U. K., however, about half the total farm consumption of concentrated feedingstuffs during the observed period was imported, and in 1964 Agreements made with the main overseas suppliers were essentially aimed at maintaining imports at the 1961/62–63/64 level. Import prices of feed components, such as the price of U. S. maize, were therefore important determinants of feed prices, and in common with other models of U. K. livestock economies[6] the feed price is specified here as an exogenous variable.

In the equations below, $f$ denotes a linear function, $+$ or $-$ denotes the sign which the coefficient of the relevant variable was expected to have on *a priori* grounds, $u_1$ to $u_7$ are disturbance terms, figures in brackets are $t$ ratios, the unbracketed figures beneath each equation are, from left to right, the coefficient of multiple determination, adjusted for degrees of freedom ($\overline{R^2}$), the Durbin-Watson statistic ($d$), and the number of observations in the sample ($n$). The theoretical function is presented first in each case, followed by the estimate of it.

**Milk production**

(2.1) $MKSL_t = f(+CH_{t-1}, +T, u_1)$

(2.2) $MKSL_t = -1360 + 0.869\, CH_{t-1}$

$$\begin{array}{ccc} (8.53) & (22.9) & \\ .97 & 1.7 & 15 \end{array}$$

The trend variable in (2.1) represents health and genetic improvements in dairy stock, but its coefficient was statistically rejected in (2.2) because milk yields per dairy cow and total cow numbers moved in a very similar manner during the observed period. Use of 2.2 in the supply model implies that changes in milk yields are counter-balanced by adjustments to the proportion of dairy cows in the total cow herd.

**Producer milk price**

(3.1)
$PRM_t = f(+GPM_t, -[MKSL - SQ]_t, u_2)$

(3.2)
$PRM_t = 0.975\, GPM_t - 0.0098\, [MKSL - SQ]_t$

$$\begin{array}{ccc} (24.7) & & (17.7) \\ .99 & 1.6 & 15 \end{array}$$

Milk is sold by the Milk Marketing Boards on behalf of producers, and government makes up any deficiency between net revenue from Boards' total sales and a standard quantity of milk valued at the average guaranteed price. Milk produced in excess of the standard quantity qualifies only for a lower price.

**End-of-year calf numbers**

(4.1) $F_t = f(+CH_{t-1}, +P'_t, +PRM_t, -FP_t$ or $-FP_{t-1}, u_3)$

(4.2)[7] $F_t - 0.214\, CH_{t-1}$

$$= -458 + 18.6\, PRM_t + 4.72\, MPB_t$$

$$\begin{array}{ccc} (1.79) & (2.08) & (3.61) \\ .79 & 1.5 & 12 \end{array}$$

(5.1) $M_t = f(+CH_{t-1}, +P'_t, -FP_t$ or $-FP_{t-1}, u_4)$

(5.2) $M_t - 0.214\, CH_{t-1}$

$$= -1750 + 9.90\, GPB_t$$

$$\begin{array}{cc} (5.29) & (6.58) \end{array}$$

$$+ 10.1\, MPB_t - 6.11\, FP_{t-1}$$

$$\begin{array}{cc} (8.09) & (1.79) \end{array}$$

$$\begin{array}{ccc} .97 & 1.9 & 13 \end{array}$$

Changes in expected prices, which are based on actual prices prevailing during the year, cause movements away from the "normal" calf:cow ratio. In the case of feed, a storable input, the previous year's price may also affect the current year's calf retentions. One reason why the feed price coefficients of 4.1 were rejected may be that male and female calves compete for resources, so that male calves that are not potential breeding stock are the ones sacrificed when feed prices rise.

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[6] For examples relating to stability analysis, see references [9] and [13].

[7] Coefficients on the left-hand side of equations (4.2), (5.2), and (6.2) were determined prior to estimation of these equations on the basis of other econometric evidence [3].

**End-of-year cow numbers**

$$(6.1)\quad CH_t = f(+CH_{t-1}, +P'_{t-1}, +PRM_{t-1}, +P'_{t-2}, +PRM_{t-2}, -FP_{t-2}, -FP_{t-1} \text{ or } -FP_{t-3}, u_5)$$

$$(6.2)\quad CH_t - 0.65\, CH_{t-1} = \underset{(5.60)}{1890} + \underset{(2.75)}{40.9}\, PRM_{t-1} + \underset{(2.67)}{4.15}\, MPB_{t-2} - \underset{(1.40)}{8.17}\, FP_{t-1} - \underset{(2.42)}{15.6}\, FP_{t-2}$$

.81 — 12

Cullings in any year are mainly planned during the previous year when the inventory of potential cows (heifers-in-calf) is being expanded or contracted. A change in cow numbers during year $t$ will therefore depend largely on prices during $t - 1$. Some attention may also be given to potential supplies of new cows for the following year, so that cow numbers may also be related to prices two years ago. Due to the few degrees of freedom available, different combinations of the price variables were fitted and the equation with the highest $\overline{R}^2$ selected.

**Young beef slaughterings**

$$(7.1)\quad S_t = f(+[M+F]_{t-2}, -\Delta^2 CH_{t,t-2}, u_6)$$

$$(7.2)^8\quad S_t = \underset{(46.7)}{0.858}\,[M+F]_{t-2} - \underset{(3.64)}{0.892}\,\Delta^2 CH_{t,t-2}$$

.77 1.6 12

The average age of steers and heifers at slaughter during the sample period has been estimated [11] to have been not much more than two years. Second differences of cow numbers are used to represent the demand on heifer inventories to supply animals for breeding instead of for sale as fatstock.

**Market beef price**

$$(8.1)\quad MPB_t = f(-[S+IMPF]_t, +Y_t, u_7)$$

$$(8.2)\quad MPB_t = \underset{(11.4)}{139} - \underset{(6.68)}{0.0547}\,[S+IMPF]_t + \underset{(9.73)}{0.0053}\, Y_t$$

.89 2.1 14

The market price of young beef is inversely related to domestic supplies, made up of home-fed animals and imported fatstock. Previous work [3] showed no significant relationship existed between annual variation in price and imports of chilled carcass beef.

**Model evaluation**

The statistical validity of the estimated supply model was assessed on its ability to reproduce or simulate historic time paths, when the only information given to the model (apart from initial values of all predetermined variables) are values for exogenous variables. Overall model performance in this respect was considered satisfactory. The plausibility of the fitted model as a quantitative description of producer response to price was judged by its impact multiplier values. Jones [10, 12] provides the only comparable estimates of long-run elasticities. His own-price beef elasticities are considerably higher than those in Table 1, but agreement on beef and milk cross-price elasticities, the own-price milk elasticity, and combined beef and milk supply elasticity is good. The model was therefore considered a sufficiently reasonable representation of supply relations to allow it to be used as a "test-bed" for examining the effect of price policies on market movements.

## Models of Government Price-Fixing Behavior

In the supply response model, guaranteed prices for beef (variable $GPB$) and milk ($GPM$) are treated as exogenous variables. The next step was to drop this assumption and add to the supply model extra equations, representing government price-fixing behavior, in which guaranteed prices are treated as endogenous variables. The policy objectives listed earlier provide a basis for specifying behavioral equations for the guaranteed prices of beef and milk.

In principle, equations expressing these prices as functions of recent movements in supplies, market prices, subsidy levels, and feed prices could be fitted to the sample data. In practice, however, it would be difficult to estimate models of government price-fixing behavior in this manner. First, policy objectives for beef and milk were not given a constant degree of emphasis throughout the observed period (1954–68). For example, the earlier adjustments to the guaranteed beef price reflected the policy emphasis on production stimulation, but this was toned down later because of the excessive cost of supporting the market price. Thus the parameters of the

[8] The method of generalized differences was used to estimate (7.2) because direct regression produced autocorrelated residuals.

Table 1. Supply elasticities for beef and milk with respect to guaranteed prices for these products and the price of cattle feed

| Product / Price | Milk Supply | | Young Beef Slaughterings | | All Beef Slaughterings |
|---|---|---|---|---|---|
| | *SR*[a] | *LR* | *SR* | *LR* | *LR* |
| Beef | −0.1 | −0.1 | +0.6 | +0.3 | +0.2 |
| Milk | +0.6 | +0.85 | −0.7 | +0.2 | +0.7 |
| Feed | −0.35 | −1.4 | +0.3 | −0.4 | n.c. |

[a] *SR* and *LR* denote short-run and long-run elasticities of supply respectively. Short-run is defined here as the period of time which elapses between change in price and consequent initial change in output.

government price-adjustment equations would have to be specified as time-dependent functions of complicated form, which would greatly reduce the degrees of freedom available. Second, the necessary inclusion of target variables such as supply and market price in the same equation gives rise to problems of multicollinearity, while another estimation difficulty is due to the high autocorrelation in the guaranteed beef price series.

Estimating government behavior equations by statistical methods was therefore ruled out. Instead, it was assumed that policy-makers obeyed completely certain prescribed rules which determined the levels at which guaranteed prices were to be set. These rules were simply informed guesses about the nature of the real government behavior equations, based on knowledge of the statutory and political factors which constrained government's freedom of action during the relevant period, and on their actual responses to what were widely known to be undesired movements in the target variables.[9] It was clear, for example, that the beef price was fixed with regard to recent discrepancies between actual and intended output movements and also in relation to the cost of producer price support. Similarly, the milk price was determined on the basis of recent changes in output, feed costs, and producer prices.

The more accurately the rules represent the real government behavior functions, the closer will the dynamic properties of the whole producer response-government correction model resemble those of the real system. One objective of this analysis was therefore to try to identify the "true" rules, to the extent that the dynamic behavior of models containing them was consistent with that observed for the beef-milk economy.

A second objective was to determine, by testing several versions of price-fixing rules, what effect different price policies would have had on the beef-milk economy. This would indicate whether alternative price-adjustment strategies to those apparently used could have been more effective in achieving policy objectives. This approach requires caution, however, because it is assumed that producers respond to expected prices, and though the supply model here assumes that past prices are taken as a guide to future ones, it has already been suggested that producers are aware of pressures acting on the government price-fixers. The historical responses of producers to guaranteed price changes therefore reflect decisions based on producers' guesses about how government did fix price levels. If producers perceive the price-fixing criteria to have been changed (represented by substituting one price-fixing rule in the model for another), then it is to be expected that the way they react to price would change also.

Ideally, therefore, whenever a guaranteed price-fixing rule, which is not considered to represent the one government actually used, is incorporated in the model, the producers' response equations should be altered to reflect their different pattern of behavior under a new price policy. For example, if it became apparent that government was prepared to tolerate higher degrees of price support than previously, then producers would probably pay less attention to market price movements and put more weight on recent changes in guaranteed prices. However, it is not easy to guess how differently producers might have behaved in the face of policies which were not applied, and attempts to do so would introduce yet more variable

[9] Thus in exactly the same way that equations (3.1) and (8.1) are intended to explain the series of producer and market prices observed, so these rules are intended to explain the guaranteed price series observed. The difference between the two approaches lies in the methods of parameter estimation and evaluation of equation validity.

parameters into the model in addition to those in the government behavior equations. Selection of price-fixing rules was therefore restricted in most cases to those which did not appear to represent drastic departures from actual policies. Hence it could be assumed that either producers would not have been aware of the new rules, or, if they were, their behavior would not have altered very much.

It will be apparent that the rules "tested" here are little more than beginners' tools for a first exercise in dynamic policy analysis. However, so little is known about the relationship between sequential price adjustment and the dynamic behavior of the beef and milk markets[10] that even simple questions can be asked which carry the expectation of having comprehensible answers.[11] Some of these questions are explored below, all concerned with the problem of stability through time.

## Rules for fixing the guaranteed price of beef

**Criterion 1: Output Regulation.**—The guaranteed price, $G$, is assumed to be adjusted each year in response to deviations of beef supply from its intended position, *viz.*

$$(9) \quad G_t - G_{t-1} = \frac{1}{\eta}(Q^* - Q_{t-1}) + k$$

where $Q^*$ and $Q$ are desired and actual production levels respectively. This rule can allow for a constant price or a constant trend in price, $k$, which is unaffected by changes in output. In period analysis all factors which exert a constant influence on the system can be ignored. $Q_{t-1}$ is output in the year preceding the announcement of the new price for year $t$ and is therefore the latest figure for production available to the controller. (Rule B1) and equation (10) below are versions of equation (9) that are used:

(Rule B1)

$$G_t - G_{t-1} = \frac{1}{\eta}(S^* - S_{t-1})$$

where $S$ is the number of steer and heifer slaughterings.

$$(10) \quad G_t - G_{t-1} = \frac{1}{\eta'}(B^* - B_{t-1})$$

where $B^*$ and $B$ are desired and actual total beef slaughterings respectively.

$B_{t-1}$ can be defined as

$$(11) \quad B_{t-1} = S_{t-1} + \tfrac{1}{5}\,CH_{t-2} + \tfrac{1}{2}(CH_{t-2} - CH_{t-1}).$$

(11) assumes a normal cow herd culling rate of 20 percent per annum and that half of any net change in the cow herd is due to a change in culling rate. The second rule for beef price thus becomes

(Rule B2)

$$G_t - G_{t-1} = \frac{1}{\eta'}[(S^* - S_{t-1}) + (C^* - 0.2\,CH_{t-2} - 0.5\,[CH_{t-2} - CH_{t-1}])]$$

where $C^*$ is desired cow slaughterings.

**Criterion 2: Unit Subsidy Level.**[12]—It is assumed that the beef price is adjusted each year according to recent movements in unit subsidy levels, *viz.*

$$(12) \quad G_t = \alpha G_{t-1} - \beta U_{t-1}$$

where $U$ is unit subsidy. For long-run analysis, the time subscripts can be dropped and (12) rewritten as

$$(13) \quad (1 - \alpha)\,G = -\beta U$$

$$\Delta U = \frac{1 - \alpha}{\beta}(-\Delta G)$$

where $\Delta$ denotes a change. Assuming that $U_t \equiv G_t - M_t$, where $M$ is the "free" market price,[13] (12) can also be written

$$(14) \quad \Delta G = \left(\frac{\beta}{1 - \alpha + \beta}\right)\Delta M.$$

Thus in the long run the level of unit subsidy moves in the opposite direction to the guaranteed price [equation (13)], i.e. the guaranteed and "free" market prices move in the same direction [equation (14)]. Writing (12) as

$$(15) \quad G_t = (\alpha - \beta)G_{t-1} + \beta M_{t-1},$$

it can be seen that $1 - \alpha + \beta$ gives the rate at which the guaranteed price is adjusted. The ratio $(1 - \alpha)/\beta$ determines how the government and producer share the cost of a change in market price in the long run.

[10] The economic significance of fluctuations in beef supplies is widely appreciated. For a recent comment on the need to find the economic causes of the less publicized changes in the U. K.'s annual milk supplies, see Williams [16].

[11] In many situations the important practical questions often require solutions of unattainable generality.

[12] The basic propositions in this section are due to Jones [9].

[13] This identity does not hold exactly, but it is an adequate approximation for present purposes.

If $(1-\alpha)/\beta = 1$, government and producers share the cost equally;
if $(1-\alpha)/\beta < 1$, government takes the smaller share; and
if $(1-\alpha)/\beta > 1$, government takes the larger share.

If $\alpha = 1$, then it is assumed that the government's objective is a fixed level of unit subsidy, since $\Delta G = \Delta M$ in the long run. An alternative way of expressing this is to write

$$(16) \qquad G_t - G_{t-1} = \lambda(U^* - U_{t-1}),$$

where $U^*$ and $U$ are desired and actual levels of unit subsidy, and $\lambda$ is a coefficient of unit subsidy adjustment. The price-fixing rule used here is

(Rule B3)

$$G_t = (\alpha - \beta)G_{t-1} + \beta M_{t-1}.$$

### Rules for fixing the guaranteed price of milk

The rules below assume that the guaranteed price is associated with a fixed standard quantity.

**Criterion: Output Regulation.**—The milk price is adjusted in the manner described in equation (9); for example:

$$(17) \quad G_t - G_{t-1} = \frac{1}{\eta''}(Q^* - Q_{t-1}) + \frac{\gamma}{\eta''}(F_{t-1} - F_{t-2}) + k'$$

where $Q^*$ and $Q$ are desired and actual milk supplies, and $F$ is the price of feed. This rule implies that government is not content with the self-regulating device for milk supply contained in the standard quantity arrangements. This certainly corresponds with observed government reaction in the earlier part of the period, when guaranteed milk prices were reduced on three occasions.

Since feed price is an exogenous influence in the model used to test this rule, its operational equivalent is

(Rule M1)

$$G_t - G_{t-1} = \frac{1}{\eta''}(Q^* - Q_{t-1}).$$

Similarly,

(Rule M2)

$$G_t - G_{t-1} = \frac{1}{\eta''}(Q_{t-2} - Q_{t-1}).$$

(Rule M2) assumes that government wishes to stabilize milk output in such a way that the most recent change observed will be reversed.

### Choosing values for $\alpha$, $\beta$, and $\eta$

The first thing to note is that the downward rate of adjustment of guaranteed prices was statutorily limited by the 1957 Agriculture Act.[14] With regard to $\alpha$ and $\beta$, it is a reasonable assumption that governments during the 1954–68 period were aiming at a fixed level of unit subsidy for beef, possibly of the order of 12–15 percent of the final producer price. Given the assumptions here, this means that $M/G = 0.85$–$0.88$. Given also the minimum 4 percent reduction allowed by the 1957 Act for annual adjustment to the guaranteed beef price, the maximum value of $\beta$ possible in practice therefore lay between $0.266'$ and $0.33'$.

Values were initially chosen for $\eta$ which seemed consistent with the relative magnitudes of price adjustment and discrepancies between desired and actual output levels which occurred since 1954. For example, (Rule B1) with $\eta = 10$ means that a shortfall of 280,000 slaughterings (approximately 70,000 tons of beef) in year $t$ would result in 28*s* being added to the guaranteed price for year $t+1$. However, assuming that the trend in slaughterings during 1954–68 can be taken as the desired growth path, there was only about a 5 percent chance of fluctuations as large as this occurring. A price of 14*s* would have been needed, therefore, in one-third of the output corrections, whereas the largest increase actually awarded was 12.3*s* (in 1955), and of the remaining nine changes made, the three largest averaged only 10.3*s*. (Rule B1) with $\eta = 10$ would therefore be rather more responsive than government behavior in practice. On the other hand, (Rule B2) with $\eta' = 40$ would have meant a change in price of less than 10*s* for 95 percent of the supply discrepancies in the past, so that this value for $\eta'$ may be nearer the mark.

(Rules M1 and M2) with $\eta'' = 100$, implies that $\pm 1.4d$ would have been needed to correct 95 percent of past milk supply fluctuations about trend, whereas in reality only half the price changes made were of 1*d* or over. This might suggest that these rules are more flexible than the "true" rules, but it should be remembered

[14] Under the terms of this Act, government may not reduce the guaranteed price of any commodity to less than 96 percent of its level in the previous year, and in the case of livestock products, any reduction must not exceed 9 percent over three years.

that in practice government was also free to adjust the standard quantity as well as the guaranteed price.

No attempt is made to develop generalizations about stability conditions. Eckaus [1] observes that for difference equations of a higher order than three (which is the case for all systems here), conditions which are both necessary and sufficient for stability are too complicated to be enlightening. Hence the approach here is to examine a few specific situations and observe how dynamic behavior changes with different rules.

## The Dynamic Properties of the Models

### The supply response model (guaranteed prices exogenous)

By eliminating all terms involving exogenous variables, the supply model can be reduced to two equations in $S$ and $CH$. The largest characteristic root of this system is complex with a modulus of 0.8181 and a dominant cycle period of 5 years.[15] The model is therefore stable: following a displacement from equilibrium, and in the absence of further external shocks (such as changes in guaranteed prices), the time path of the model will eventually return to equilibrium. This can be compared to Foote's feed-livestock model which is explosive, the largest root being 1.5404, Reutlinger's beef model which is heavily damped, the largest root modulus being 0.527, and Jones's two pig supply models, with root moduli of 0.90 and 0.95.

### The supply response model with price-fixing rules (guaranteed prices endogenous)

The main results are shown in Table 2, the largest root being used to indicate the stability of government-producer interaction. Cycle periods are also shown, with the dominant cycle listed first.

The hypothetical effects of introducing the price-fixing procedures discussed above into the beef-milk economy can be summarized as follows:

(i) Setting forward prices which remain unchanged for several years at a time, as suggested for example by Thomas [15], stabilizes the beef market more effectively than using the beef price-fixing rules specified. Thus the unmodified system, the supply model without any price-fixing equations, is more damped than any of the systems with beef price-fixing rules (Table 2, Section A). The unmodified model represents a situation where guaranteed prices remain constant despite changes in supplies and market prices. It should be emphasized that this system cannot reveal anything about the stability of a completely free economy with no guaranteed prices, because the model itself is estimated from data generated by a system in which guaranteed prices were operating. It is interesting to note that Jones [9] concluded that an unchanged guaranteed price would in theory stabilize the pig cycle very effectively.

(ii) There is little difference between the four approaches to beef price support considered ($([1-\alpha]/\beta = 0, 1, > 1$ or $< 1)$. As might be expected, the degree of stability depends more on the rate at which the government price can be adjusted each year. As the rate of adjustment increases ($\alpha - \beta$ decreases), so the system becomes increasingly unstable (Table 2, Section B).

(iii) The simultaneous use of (Rule B3), aiming at a fixed level of unit subsidy, with (Rule M2), which aims at stabilizing milk supply at the previously observed level, results in persistent six and one-half year cycles. Use of the regulatory rule for total beef supplies (Rule B2) in place of (Rule B3) has the same effect (Table 2, Section C). Correlogram analysis suggests cycles in non-breeding cattle numbers are about five years in length but that cycles in cow numbers are about six years [3]. Given the "confidence intervals" subjectively associated with correlogram estimates of the fundamental periods of actual cycles, this system's cycles can be regarded as consistent with the real cycle period.[16] Hence (Rules B2, B3, and M2) could be accepted as valid models of government behavior by this criterion.

(iv) For a given value of $1/\eta'$, the government's "elasticity of response," in (Rule B2) the cycles generated become in-

[15] Cycle periods are rounded off here to the nearest half-year.

[16] Estimates of the length of the actual U. K. cattle cycle were obtained from correlograms of residuals of trends fitted to annual observations on cattle inventories [3]. No significance tests have been devised for correlograms, so what constitutes a good estimate of the fundamental period is a matter of judgment.

**Table 2. Characteristic roots and cycle periods of the supply model with guaranteed price-fixing rules**

A. Rules for the Guaranteed Price of Beef Only[a]

| Rule | Value of $\eta$ or $\eta'$ | Moduli of Largest Roots | Cycle Periods (years) | |
|---|---|---|---|---|
| B1 | 10 | 1.0718 | 7, | 7½ |
| B2 | 10 | 1.1051 | 7, | 5 |
| | 40 | 0.8765($R$),[b] 0.820 | 6, | 5½ |

| Rule | $\beta$ | Value of $(\alpha-\beta)$ | $(1-\alpha)/\beta$ | Moduli of Largest Roots | Cycle Periods (years) | |
|---|---|---|---|---|---|---|
| B3 | 0.1 | 0.9 | 0 | 0.8700($R$), 0.8295 | 5½ | 5½ |
| | 0.33 | 0.66 | 0 | 0.8752 | 5½ | 9 |
| | 0.66 | 0.33 | 0 | 0.9609 | 5½ | 6½ |
| | 0.15 | 0.7 | 1 | 0.8427 | 5½ | 5½ |
| | 0.33 | 0.33 | 1 | 0.8955 | 5½ | 6 |
| | 0.3 | 0.5 | $<1$ | 0.8814 | 5½ | 6 |
| | 0.5 | 0.25 | $<1$ | 0.9320 | 5½ | 6 |
| | 0.2 | 0.5 | $>1$ | 0.8607 | 5½ | 5½ |
| | 0.5 | $-0.5$ | $>1$ | 0.9114 | 5 | 5½ |

B. Rules for the Guaranteed Price of Milk Only

| Rule | Value of $\eta''$ | Moduli of Largest Roots | Cycle Periods (years) | |
|---|---|---|---|---|
| M1 | 100 | 0.9919 | 9½ | 4½ |
| M2 | 100 | 1.0000($R$), 0.9885 | 6½ | 4 |
| | 1,000 | 1.0000($R$), 0.8043 | 5½ | 5 |

C. Rules for Both Guaranteed Prices

| Rule | Value of $\alpha$ | $\beta$ | $\eta'$ | $\eta''$ | Moduli of Largest Roots | Cycle Periods (years) | |
|---|---|---|---|---|---|---|---|
| | | Realistic Values | | | | | |
| B2 M2 | — | — | 40 | 100 | 1.0000($R$), 0.9959 | 6½ | 4½ |
| B3 M2 | 1 | 0.33 | — | 100 | 1.0095 | 6½ | 4½ |
| | | Experimental values | | | | | |
| B3 M2 | 1 | 0.10 | | 20 | 1.4080 | 6½ | 4 |
| | 1 | 0.10 | | 1000 | 1.0000($R$), 0.8056 | 5½ | 5 |
| | 1 | 0.90 | | 20 | $-1.9702$($R$) | 6½ | |
| | 1 | 0.90 | | 1000 | $-1.9527$($R$) | 6½ | 3 |
| | 1 | 0.20 | | 200 | 1.0000($R$), 0.8943 | 6½ | 4½ |
| | 1 | 0.60 | | 1000 | 1.0000($R$), 0.7807 | 6½ | 7 |

[a] The results relate to a situation where the guaranteed beef price is adjusted according to the criteria above, but the guaranteed milk price is kept unchanged regardless of market conditions.
[b] $R$ denotes a real root; all other moduli shown belong to complex roots.

creasingly damped as the rate of adjustment of productive capacity (cow numbers) in equation (7.1) decreases. This conforms with the stability condition for the simple partial adjustment model of supply.

The coefficients assumed for price-fixing (Rules B3 and M2) are estimates, albeit rather crude ones, of governments' actual response parameters during the relevant period. It is tempting to push beyond the realms of "what seems to have happened" into those of "what might have

happened if things had been different." The dynamic properties of systems containing (Rules B3 and M2), with values for $\beta$ and $\eta''$ varying from 0.1 to 0.9 and from 20 to 1,000 respectively, were therefore investigated. A policy of a fixed degree of beef price support was maintained so that $\alpha = 1$ in each case. The results (which must be treated with circumspection for, as stressed earlier, if government behavior had been different, then so presumably would producer behavior have been) show the system is most damped when $\beta = 0.6$ and $\eta'' = 1{,}000$, and most explosive when $\beta = 0.9$ and $\eta'' = 20$ (Table 2, Section D). Provided that the guaranteed milk price is not changed by more than $0.28d$ per annum (implying a value of 500 for $\eta''$, according to the method of estimating the "true" value of $\eta''$ outlined above), the rate of adjustment of the guaranteed beef price can be increased up to 60 percent per annum ($\beta = 0.6$) and the system will still be slightly more stable than if guaranteed prices are simply kept unchanged. The smallest (non-zero) adjustment actually made to the guaranteed milk price was $0.25d$ in 1957 and the largest was $2.5d$ in 1964, which can be regarded as equivalent to values of $\eta''$ of 560 and 56 respectively.

## Taking account of initial conditions

The system consisting of the supply model with (Rules B3 and M2) has a 7th-order determinantal difference equation so that its partial solution contains seven roots. For a complete solution, seven initial conditions must be specified and satisfied by this equation. Complete solutions would show whether the conclusions drawn concerning the stabilizing effects of the price-fixing rules would remain valid in a system defined in terms of observed dynamic behavior. The trigonometric form of the $i$th complex root of equation (1) can also be written as $V_i(D_i)^t$ $(\cos tR_i - \Phi_i)$, where $V_i$ and $\Phi_i$ are arbitrary constants derived from the expression ($f_i \cos tR_i + g_i \sin tR_i$). In the partial solution, with $V_i$ and $\Phi_i$ undetermined, $D_i$ could be the dominant root modulus and if near to unity would be interpreted as implying persistent cycles. If, however, the value of $V_i$ which satisfies certain initial conditions is very small, then the influence of this particular root on the system's behavior is correspondingly reduced. It is therefore worth investigating whether initial conditions might modify the conclusions drawn above.

Initial conditions for the system containing (Rules B3 and M2) were specified by giving variables the values observed for them in the years 1958, 1959, and 1960. With exogenous variables held at their 1960 values, a 50 year time path was generated. The nature of such a path will be identical to that obtained from a complete solution of the model which satisfies initial conditions comprising 1958, 1959, and 1960 values plus subsequent values predicted by the model. This exercise confirmed the result suggested by the partial solution (Table 2, Section C): cycles in young beef slaughterings and cow numbers showed a double period of 13 years, and their amplitude increased very gradually as time passed. This suggests that the partial solutions can be fairly confidently used as evidence for the stabilizing effects of price-fixing rules under conditions consistent with the historic behavior of the beef-milk sector.

## The effect of random variation in milk "yields"

Equation (2.1) of the supply response model defines annual milk supply as a function of the size of the cow herd at the beginning of the year. Use of this equation in policy analysis confines governments' stabilizing activities to price adjustment in response to changes in cow numbers. In fact a fairly considerable variation in annual milk supplies is due to the effects of weather on nutrient yields of grass. The effect of price-fixing procedures on the behavior of the beef-milk sector would be tested more realistically if this random variation in milk output could be allowed for.

The system containing (Rules B3 and M2) was used in an experiment to find what effect random disturbances in the milk supply equation have on dynamic behavior.[17] Figures 1 and 2 show 50-year time paths for young beef slaughterings, following a displacement of the supply response/price-fixing system from equilibrium, under four different policies. Figure 1 (path A) shows that in the absence of the milk yield fluctuations and with no adjustment to guaranteed prices, the beef market stabilizes quickly in a succession of five-year dampening cycles. The effect of random variation in milk supplies is to prolong beef market instability considerably and to make the fluctuations much more irregular [Fig. 1 (path B)]. Government intervention to support the beef price in this situation, using (Rule B3), results in cycles of greater amplitude than if the

[17] Values for $u_1$ in equation (2.1) were drawn at random for each predicted year from the distribution $N(0, [28.43]^2)$ million gallons, where 28.43 is the standard deviation of the residuals of (2.2).

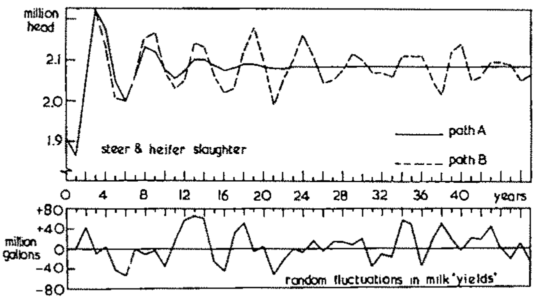


Figure 1. Milk yield variation and market stability

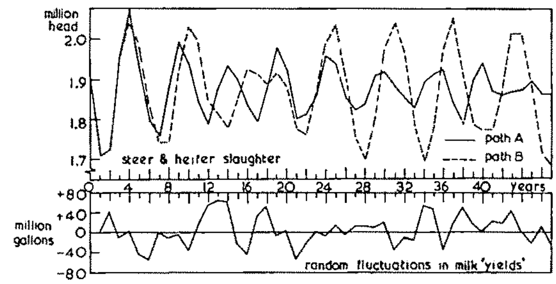


Figure 2. Milk yield variation and market stability

guaranteed price is left unchanged [Fig. 2 (path A)], a result in accordance with the difference equation solution (Table 2, Section A). If government reacts by intervening in both beef and milk markets, supporting prices in the former using (Rule B3) and regulating supplies in the latter using (Rule M2), Figure 2 (path B) shows the result to be persistent instability—as suggested already by Table 2, Section C.

## Conclusions

By the usual criteria for judging model performance, some degree of success can be claimed: an empirically estimated model of beef and milk supply, modified to include equations defining hypothetically how government adjusted guaranteed prices, generates cycles which resemble the fluctuations observed in the markets for those commodities. Some indication has also been given of the relationship between the degree of government response and market stability. It is clear, however, that much more experimentation with the form of price-fixing models is needed before the reasons for persistent instability in the beef-milk sector under guaranteed price policies can be stated with any certainty.

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# Multi-Frequency Cobweb Model: Decomposition of the Hog Cycle*

HOVAV TALPAZ

The Cobweb Theorem and the harmonic motion models are extended and integrated to form a multi-frequency cobweb model explaining the U. S. hog production cycle. The cycle is estimated by a finite, time-based Fourier Series allowing amplitude and frequency analysis. Six different cycles are discovered operating simultaneously in the attempt to reach a market equilibrium. An independent distributed lag model is estimated, verifying the fundamental hypothesis of the model. The implication is that improved industry performance can be efficiently achieved by control policies to dampen the harmful long period cycles, leaving the short ones unaffected.

*Key words:* Hog cycle; multi-frequency motion; Cobweb Theorem; Fourier Series; policy control.

SINCE the formulation of the Cobweb Theorem by Ezekiel in 1938 [2], attempts have been made to explain the hog cycle in the cobweb framework [1, 5, 12]. Harlow modified the Cobweb Model to reconcile the emerging four-year cycle with the theoretical two-year cycle [5]. An important approach was later suggested by Larson who considered the hog cycle as true harmonic motion arising from feedback and closely related to the theory of inventory cycles [8]. Larson concluded that "... the nature of the supply response differs fundamentally from that of the Cobweb Theorem where producers' decisions are assumed to refer to a short run supply curve. This is the feature of the model that leads to a four-year cycle instead of the two-year cycle that most naturally emerges from the Cobweb Theorem" [8, p. 375]. Criticizing the Cobweb Model, Larson points out that "... even when the cycle is operating in its purest, most uninterrupted manner, producers' decisions are in the appropriate direction half of the time (as opposed to the Cobweb Theorem where they are always wrong) ..." [8, p. 386]. Nerlove's distributed lag approach was another significant contribution for the understanding of the dynamic behavior of the supply response [10]. It thus appears clear that each of the above three models, standing alone, fails to satisfy the requirements of a realistic, flexible, explanatory, descriptive, and accurate model.

The primary objective of this paper is to develop and apply a theory of the hog cycle as a Multi-Frequency Cobweb Model arising from feedback signals, short, intermediate, and long run disequilibrium positions. As will be shown, none of the above mentioned approaches will be dismissed, since *all* of them are important in building the model and/or explaining its rationale.

## The Model

The basic structure of the Multi-Frequency Cobweb Model is shown in Figure 1. On a Price-Quantity plane, linear long run demand-supply curves are drawn ($D_1$ and $S_1$). Following F. V. Waugh [14], the following interpretation is offered: the $D_1$ curve shows how current prices are related to current market output. The $S_1$ curve ("lagged output") shows how current output is related to past prices [14, p. 733]. This convention can be distinguished from the demand-supply relationships of the static theory formulated by Cournot and Marshall.[1] For present purposes it became necessary to extend the Waugh definitions. Anticipating cyclical behavior as suggested by the Cobweb Theorem, "current" refers to one-half the time span required to complete one cycle. For example, $D_1$ refers to a time span of two years (one-half of a four-year cycle). $S_1$ represents the lagged supply response for the corresponding two-year period.

Point $A$ is the long run equilibrium position. Points $B_1$, $B_2$, $B_3$, and $B_4$ are the traditional Cobweb price-quantity coordinates as developed by Ezekiel and his followers. The rectangle

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[1] However, this distinction is not critical for the present argument.

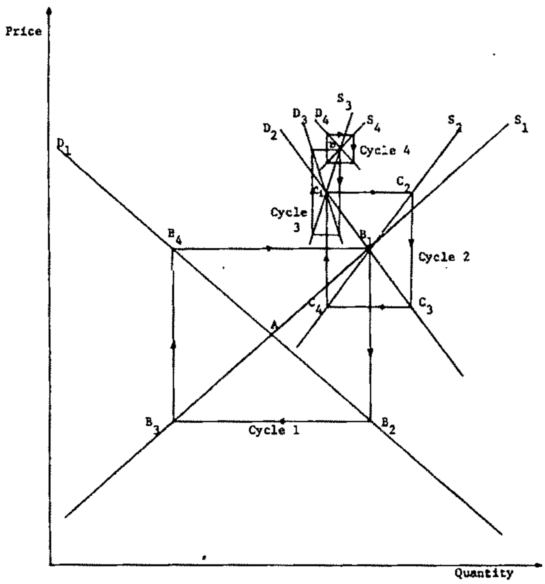



**Figure 1. The Multi-Frequency-Cobweb Model with four frequencies or cycles**

$B_1\ B_2\ B_3\ B_4$ represents the assumption of a continuous Cobweb locus (neither converging nor explosive) that simplifies the exposition. The corners of the rectangle can be interpreted as the "intended" price-quantity coordinates or the long run disequilibrium points *if* no other forces are imposed and Ezekiel's three conditions hold [2]. One of these conditions implies a price lagged at a single and fixed time interval. If this time interval is exactly two years, then cycle 1 should be completed in exactly four years.

A second lagged price is then introduced as another stimulus. The two signals are allowed to operate separately with appropriate weights corresponding to their influence on the producers' decision process. It should be clear that $D_2$ and $S_2$ are the intermediate demand-supply curves intersecting each other at the long run disequilibrium point $B_1$. The arbitrary rectangle $C_1\ C_2\ C_3\ C_4$ forms a two-year Cobweb cycle (cycle 2).[2] That is, if the two-year price lag stimulus did not exist, then what is left is the traditional Cobweb Model with a locus about the equilibrium point $B_1$. Postponing the discussion of the simultaneous time lags influence, it is sufficient to say at the moment that in the simultaneous case neither cycles 1 nor 2 will remain the same as is presented in Figure 1.

Proceeding in the same fashion, additional price stimuli lagged six and three months will generate cycle 3 and cycle 4 about points $C_1$ and $D$ respectively. Notice that the time period for completion of a cycle is exactly one half the time of the preceding cycle. Hence, by the time cycle 1 is completed, two are completed for cycle 2, four for cycle 3, and eight for cycle 4.

The number of cycles and their duration for a particular system are determined by the behavior of that system. The geometric properties of each rectangle are fully determined by the system behavior. The size and shape of the rectangle has a crucial influence on the final overall locus of the price-lagged vs. quantity intersection points. There is a direct relationship between the rectangle's size and its contribution to the final locus. As in the Cobweb Theorem case, the direction of the motion is clockwise simply because the output is lagged after the price and not vice versa.

The Cobweb Theorem is somewhat inflexible when it suggests that the time path between any two corners ($B_1$ and $B_2$, for example) should be a straight line. While this assumption might be true in situations involving some annual cash crops, it is completely inadequate in livestock production where the adjustment process is a continuous one generating a very interesting time path of too great importance to be ignored (See Figs. 2 and 3). In fact, under a continuous adjustment process the traditional Cobweb with its four rectangular corners ($B_1$, $B_2$, $B_3$, $B_4$) is replaced by a circle or ellipse. As proposed by Larson, the adjustment may be described as a process of harmonic motion.[3]

For illustration, consider the Cobweb formulation. In the simplified Cobweb case there are two basic functions for each cycle considered separately and independently.

(1.1) Demand or Price:

$$P_{it} = a_i - b_i Q_{it}$$

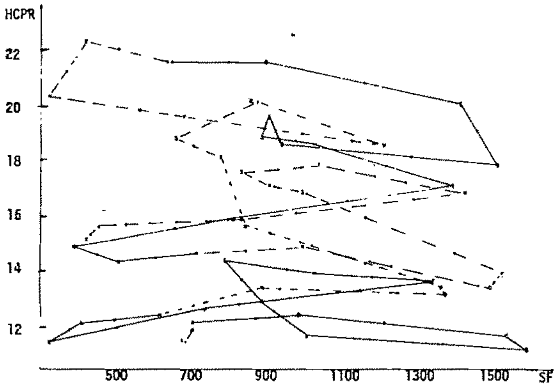
(1.2) Supply or lagged output:

$$Q_{i(t+k_i)} = C_i + d_i P_{it}$$
$$i = 1, 2, \ldots, n \text{ cycles.}$$

$b_i$ and $d_i$ are the slopes of the demand and supply curves respectively for cycle $i$ where $d_i = -1/b_i$ for a continuously oscillating model, since for the linear case a necessary condition is given by $(b_1 d_1)^2 = 1$. The time period required to complete one half of cycle $i$ is $k_i$. It is clear from (1.1) and (1.2) that if what is happening on time intervals between $t$ and $t + k_i$ is of in-

[2] The corner $B_1$ was selected for convenience. Any other point on the rectangle could serve as well.

[3] This is not necessarily true harmonic motion. See [8, pp. 379–381].




Sources: [17, 18].

**Figure 2. Hog-Corn Price Ratio (HCPR) vs. Sows Farrowed (SF), Jan. 1964–Dec. 1967, reported data**

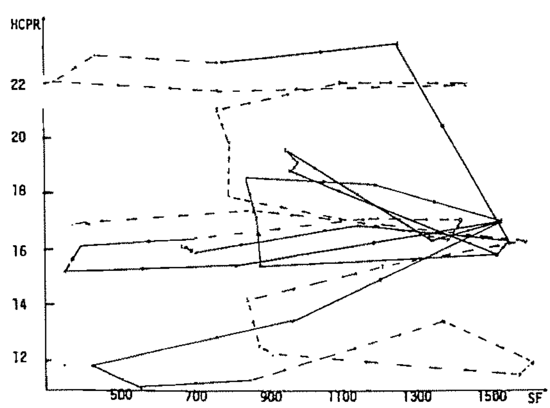
terest, the Cobweb formulation is incapable of providing this information.

Larson [8, p. 378] suggests using the trigonometric function cosine to express price and quantity:

$$(2.1) \qquad P_t = \text{COS}\,\frac{2\pi t}{48} + e_p$$

$$(2.2) \qquad Q_t = \text{COS}\,\frac{2\pi t}{48} + e_q$$

where 48 stands for a four-year cycle with months as units, and $e_p$ and $e_q$ are phase angles depending on initial conditions. This set of equations gives a fixed amplitude four-year circular cycle. The contribution of this model is its intuitive power of explanation and the fact that the rate of change with respect to time, or the first derivative, is another similar trigonometric function that is actually the same function phased in time and different in amplitude—a very important property possessed by systems with feedback. However, for practical purposes Larson's model falls short as a sufficient and workable model[4] because of two basic shortcomings. First, it is implied that the frequency and amplitude of price and quantity are fixed and equal to each other. Second, the model dismisses the existence of other shorter cycles (higher frequency cycles). These two points can be seen to be incorrect by a quick look at Figures 4 and 5. There is not a pure single cosine curve in either the hog-corn price ratio variable or the number of sows farrowed variable.




Sources: [17, 18].

**Figure 3. HCPR vs. SF, Jan. 1968–Dec. 1971, reported data**

## The Econometric-Mathematical Model Representation

For representation and approximation of price and quantity over time, the Fourier Series was chosen because of its desirable and convenient properties, some of which will be discussed here. The Fourier Series [13, p. 655] may take several different forms from which the following for the stochastic cases were selected:[5]

$$(3) \qquad \phi_m(t) = \sum_{n=0}^{m} (a_n\,\text{COS}(nw_ot) + b_n\,\text{SIN}(nw_ot)) + e$$

where

$\phi_m(t)$ = the time variable to be approximated,
$m$ = integer, the maximum number of terms in the series,
$w_o$ = $2\pi/T$ is the fundamental radian frequency related to the base period $T$,
$T$ = the time period needed to complete the major cycle; in this case $T =$ 48 months, also called the base period,
$t$ = time count in month units,
$e$ = the error term.

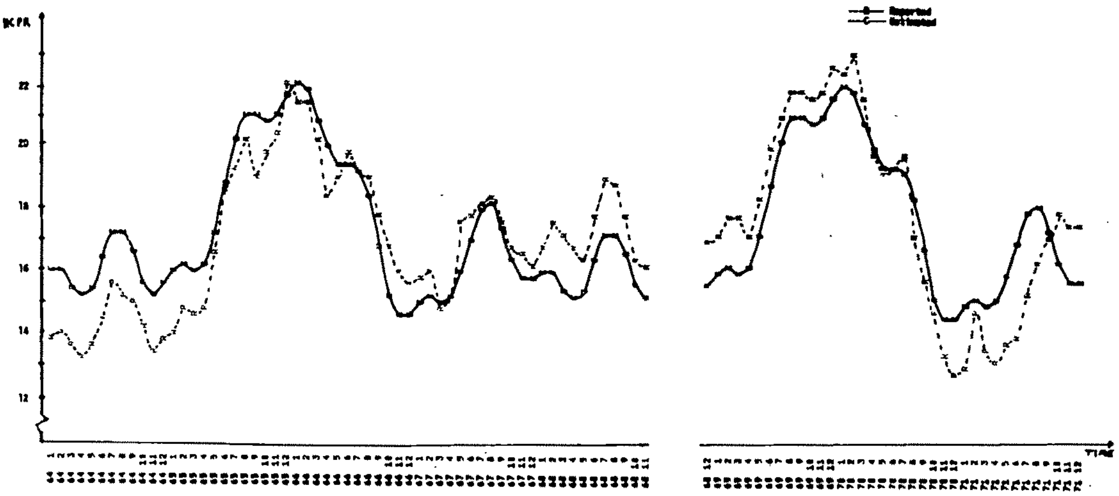
Using least squares method to estimate $\phi_m(t)$, one obtains

$$(4) \qquad a_n = \frac{2}{T}\int_{t_o}^{t_o+T} (\phi(t)\,\text{COS}(nw_ot))dt$$

$$b_n = \frac{2}{T}\int_{t}^{t_o+T} (\phi(t)\,\text{SIN}(nw_ot))dt.$$

[4] It is possible that Larson did not intend to go beyond the basic theoretical features of his model.

[5] Thomas [13, pp. 655–657] and Manetsch and Park [9, pp. 3–12 and 3–22] will be followed for the mathematical properties of the Fourier Series.



Source: [17].

Figure 4. HCPR (bu. corn/cwt. liveweight), reported vs. estimated values, 1964–1971

This property also guarantees orthogonality, which provides the following convenience. If the function $\phi_m(t)$ is approximated by the trigonometric polynomial $\phi_n(t)$ substituting (4) into (3), and then another approximation $\phi_k(t)$ using more terms $(k > m)$ is taken, more terms may be added to (4) without changing any of the coefficients $a_o, \ldots, b_n$ used in the first approximation. For orthogonality to hold in a stochastic Fourier Series of the form given by (3), it was shown by Fishman that the following conditions must hold [4, pp. 15–17]:

(4.1) $E(a_n a_k) = E(b_n b_k) = E(a_n b_k) = 0$ for $n = k$,

and

(4.2) $E(a_n^2) = E(b_n^2)$ for $n = 1, \ldots, m$.

The orthogonal property is of extreme importance because where $n = o, \ldots, m$, the result is what Fisher and Ando [3] called different "completely decomposable" sets of variables or absolutely ceteris paribus conditions. This is the property that makes it possible to decompose the hog cycle, to be elaborated below. In conclusion, something is gained by taking the Fourier Series model versus Larson's harmonic motion model *without losing* any of its representative and exploratory attributes. Making use of this

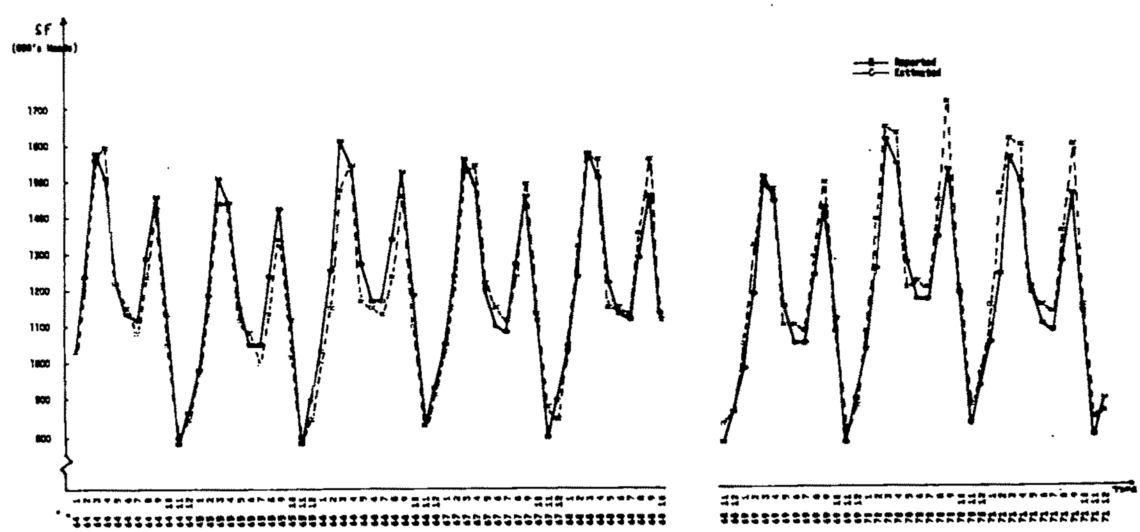


Figure 5. Sows Farrowed (SF) (000's heads), reported vs. estimated values, 1964–1971

characteristic, the value of $n$ is capable of representing a cycle with frequency equal to $T/n$. The motion of each cycle is totally independent of the motion in the other cycles. The coordinates of the price-quantity values are given by solving (4) for both price and quantity and substituting into (3). This implies that the ultimate location is determined by a summation of all the cycles and their corresponding time coordinates.

## Methodology, Procedures, and Data

To apply the model to the hog production industry, variables were selected to represent the "price" and "quantity" discussed above. For "quantity," a policy variable was sought with an impact that is crucially decisive in determining the quantity supplied to the market, yet reflecting short, intermediate, and long run considerations and minimally affected by past decisions. A direct approach might lead to the selection of total quantity marketed (heads or pounds of hogs), but this variable is too much a result of past breeding rates decisions. The percent of sows bred could meet the qualification satisfactorily. It is this breeding rate that is the major operative (contrary to the strategic) decision made by the producers concerned with market price conditions. Unfortunately neither breeding rate nor accurate breeding herd population data are available on a national basis, but the number of sows farrowing (SF) is available[6] and may serve as a good proxy for the breeding rate decision made almost four months earlier.

For "price," the Hog-Corn Price Ratio (HC PR) was selected to reflect both the product and input prices. Hog Price (HP) is the barrows and gilts average price/cwt. received by farmers in the seven major markets. Corn Price (CP) is Corn No. 2 price received by farmers at Omaha [17, 18] (monthly time series). Figures 4 and 5 show the nationally reported HCPR and SF respectively. By Ordinary Least Squares (OLS), the coefficients $a_n$ and $b_n$ were estimated for both variables, and by using a Step-wise Delete Routine [11], applying the statistical-equivalent model to equation (3), all cosine or sine terms were deleted unless a 2 percent significance level was satisfied. The results are given in Table 1 covering the period 1964–1971 on a monthly basis.

[6] See [15 and 16]. Monthly farrowing for 1968–70 was computed using 1955–67 average percent of quarterly total on reported quarterly data reported in units of 1000 head [15, 16].

Equations (5) and (6) below are the prediction equations for HCPR and SF as functions of time only. A special purpose computer simulation program was designed to map the price-quantity, or more particularly, HCPR-SF coordinates on the HCPR-SF plane. As mentioned above, equations (5) and (6) represent a linear summation of "completely decomposable" independent variable sets or cycles. Using this attribute, a "filter" was imposed on (5) to yield (6) capable of filtering through each individual cycle and by the same simulation program to trace out the time path of each cycle, combination of two or more cycles working simultaneously and, finally, all of them together.

## Empirical Results and Interpretations

### Estimated predictable equations

Applying equation (3) as a set up system for the Step-wise Delete Routine [11], $n$ is allowed to take the values $n = 0.5, 1, 2, \ldots, 18$, and the threshold significance level for including variables was 2 percent. Table 1 shows the estimated coefficients for the SF; the rest of the coefficients are not significantly different from zero.[7]

Table 1 and the other statistical measurements suggest that the SF variable is highly explainable by the independent variables set. The amplitude of each cycle is given by the absolute value of its regression coefficient if only one trigonometric function is involved at this frequency. For example, the amplitude of the four-year cycle is 46.44. If both sine and cosine variables are involved at a particular frequency, the amplitude is equal to a phase combination of the two coefficients. Figure 5 shows the estimated SF using Table 1 coefficients. The success of the estimation is evident when it is compared with the reported SF.

Table 2 shows the estimated regression coefficients for the HCPR, including only those significantly different from zero. Figure 4 shows the estimated HCPR using Table 2 coefficients. Five cycles were discovered for HCPR: 48, 24, 16, 12, and 6 months cycles. The D. W. value shows a strong serial-correlation that tends to inflate the $t$-values, but Figure 5 still indicates a close approximation of the estimated and reported time paths.

[7] All $a_n$, $b_n$ coefficients will be set to zero unless accepted on the basis of the $t$-test with 2 percent critical area. Space consideration does not permit the reporting of the correlation matrix, but it is important to notice that the requirements given by relationships (4.1) and (4.2) were not absolutely met.

Table 1. Regression coefficients for the Sows Farrowing (SF) estimation in units of 1000 head

| Independent Variable | Cycle Period (Months) | Frequency in 4 Years | Regression Coefficient | Standard Error of Coefficient | $t$-value | Significance Level |
|---|---|---|---|---|---|---|
| Constant | — | — | 1029.88 | 10.31 | 99.86 | <0.0005 |
| $\cos(4w_ot)$ | 12 | 4 | —207.91 | 14.36 | —14.48 | <0.0005 |
| $\cos(8w_ot)$ | 6 | 8 | —372.03 | 14.33 | —25.96 | <0.0005 |
| $\cos(12w_ot)$ | 4 | 12 | 48.70 | 14.33 | 3.39 | 0.001 |
| $\cos(16w_ot)$ | 3 | 16 | 99.09 | 14.33 | 6.91 | <0.0005 |
| $\sin(1w_ot)$ | 48 | 1 | —46.44 | 14.51 | —3.20 | 0.002 |
| $\sin(2w_ot)$ | 24 | 2 | 55.15 | 14.62 | 3.77 | <0.0005 |
| $\sin(4w_ot)$ | 6 | 4 | 130.71 | 14.34 | 9.11 | <0.0005 |
| $\sin(12w_ot)$ | 4 | 12 | 57.72 | 14.33 | 4.03 | <0.0005 |
| $\sin(16w_ot)$ | 3 | 16 | 54.24 | 14.33 | 3.79 | <0.0005 |

$R^2 = 0.9363$; $\bar{R}^2 = 0.9286$; $F$-value $= 120.9$; Significance level $<0.0005$;
Standard error of estimation $= 92.85$; D.W. $= 1.30$.[a]

[a] D.W. is the Durbin-Watson statistic.

## Graphical decomposition of the estimated hog cycle

In a matrix formulation (3) can be written as follows:

$$(5) \quad \phi_m(t) = [a_o, \ldots, a_m, b_1, \ldots, b_m] \times \begin{bmatrix} 1 \\ \cdot \\ \cdot \\ \cdot \\ \cos(1w_ot) \\ \cos(mw_ot) \\ \sin(1w_ot) \\ \cdot \\ \cdot \\ \cdot \\ \sin(mw_ot) \end{bmatrix}$$

The coefficients row vector is a $1 \times (2m + 1)$ matrix, and the trigonometric column vector is a $(2m + 1) \times 1$ matrix. If an identity matrix dimensioned $(2m + 1)$ is inserted between the two vectors, the value of $\phi_m(t)$ will not be altered.[8]

$$(6) \quad \phi_m(t) = [a_o, \ldots, a_m, b_1, \ldots, b_m] \times \begin{bmatrix} 1 & & 0 \\ & \ddots & \\ 0 & & 1 \end{bmatrix} \times \begin{bmatrix} 1 \\ \cos(1w_ot) \\ \cdot \\ \cdot \\ \cdot \\ \cos(mw_ot) \\ \sin(1w_ot) \\ \cdot \\ \cdot \\ \cdot \\ \sin(mw_ot) \end{bmatrix}$$

[8] Obviously the last two matrices are multiplied, then the product vector is multiplied by the first one.

Table 2. Regression coefficients for the HCPR estimation (unit: bushels of corn/cwt. hogs)

| Independent Variable | Cycle Period (Months) | Frequency in 4 Years | Regression Coefficient | Standard Error of Coefficient | $t$-value | Significance Level |
|---|---|---|---|---|---|---|
| Constant | — | — | 16.63 | 0.18 | 94.95 | <0.0005 |
| $\cos(1w_ot)$ | 48 | 1 | —2.80 | 0.25 | —11.13 | <0.0005 |
| $\cos(2w_ot)$ | 24 | 2 | 2.27 | 0.25 | 9.01 | <0.0005 |
| $\cos(3w_ot)$ | 16 | 3 | —0.74 | 0.25 | —2.93 | <0.0005 |
| $\cos(4w_ot)$ | 12 | 4 | —0.63 | 0.25 | —2.57 | 0.012 |
| $\sin(3w_ot)$ | 16 | 3 | —0.60 | 0.25 | —2.41 | 0.019 |
| $\sin(4w_ot)$ | 12 | 4 | —0.67 | 0.25 | —2.66 | 0.009 |
| $\sin(8w_ot)$ | 6 | 8 | 0.82 | 0.25 | 3.36 | 0.001 |

$R^2 = 0.7831$; $\bar{R}^2 = 0.7631$; $F$-value $= 39.20$; Significance level $<0.0005$;
Standard error of estimation $= 1.58$; D.W. $= 0.222$.

The identity matrix is easily converted into a "filter" matrix by (7):

(7) The "filter" matrix $\equiv$

$$\begin{bmatrix} 1 & & & & & & & & \\ & \alpha_1 & & & & & & 0 & \\ & & \cdot & & & & & & \\ & & & \cdot & & & & & \\ & & & & \alpha_m & & & & \\ & & & & & \beta_1 & & & \\ & & & & & & \cdot & & \\ & 0 & & & & & & \cdot & \\ & & & & & & & & \beta_m \end{bmatrix}$$

where $\alpha_1, \ldots, \alpha_m, \beta_1, \ldots, \beta_m$ are binary zero-one variables.

Using (7), any particular cycle, or combination of cycles, can be "filtered out." For example, if the four-year cycle is desired, all $\alpha$'s and $\beta$'s except $\alpha_1 = \beta_1 = 1.0$ would be set to 0. This idea was translated into a computer simulation program with the additional capability of locating the coordinates on the price-quantity plane. The results are shown in Figures 2–3 and 6–16. In each figure the starting point is indicated by a small arrow called $t_o$. The plane coordinates are mapped in alphabetical order by the computer; the connecting lines are manually drawn. The time path of the first year in most cases is marked by a continuous straight line;[9] for the second year broken lines were used, continuous lines for the third, and so on. Where the cycle is shorter than one year or the sequential points are close to each other, only a continuous line is used, and the time borders can be inferred by the alphabetical order.

Figures 2 and 3 show the reported time paths of two consecutive four-year HCPR-SF intersections. It can be seen that the year 1964 is similar to 1968 and that 1965 is similar to 1969. It can also be seen that 1966 resembles 1970, and 1967 resembles 1971 in the overall trend, but they differ in the detailed time path. This observation alone should suggest that some particular multi-frequency cycles are present.

By using the coefficients of the regressions equations summarized in Tables 1 and 2, a time path of the relationship between estimates SF and estimated HCPR was derived and diagrammed in Figure 6. By comparing this diagram with those derived from reported data, it can

[9] It is assumed that a straight line is as good as any other. Shorter intervals are of no interest here.

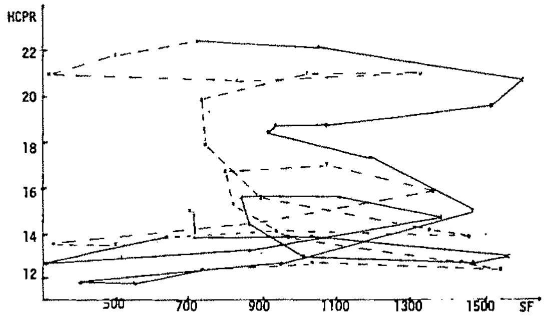



**Figure 6. Four-years estimated HCPR vs. SF**

be seen that the estimated equations yield similar turning points on the cycle as well as similar slopes on the corresponding connecting lines in the diagrams. As would be expected with different patterns for the reported four-year periods, the estimated equations trace a time path somewhere between the two. It is appropriate to use this estimated equation with the filter process described to observe the time paths traced by systematically decomposing the cycle.

Figure 7 depicts the four-year cycle as an ellipse with a clockwise motion. This time path clearly reminds one of a Cobweb continuous motion or of Larson's modified harmonic motion. Referring to the two-year cycle shown in Figure 8, note that it looks very much like the four-year cycle with twice the velocity. The starting points are not in the same position, simply indicating

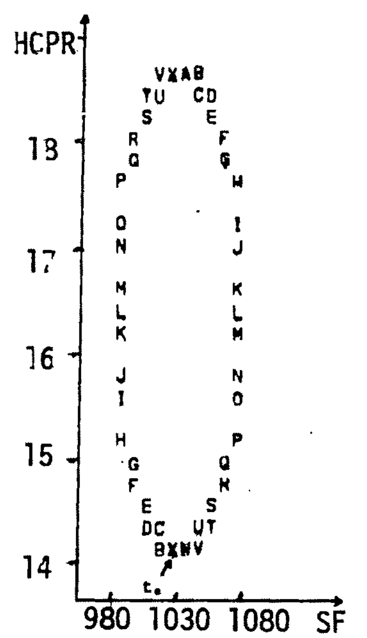



**Figure 7. Four-year cycle**

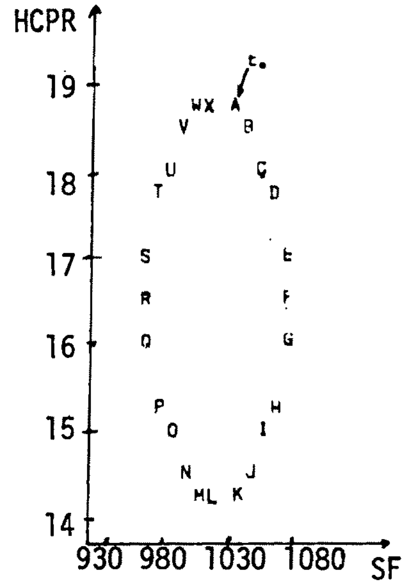



Figure 8. Two-year cycle

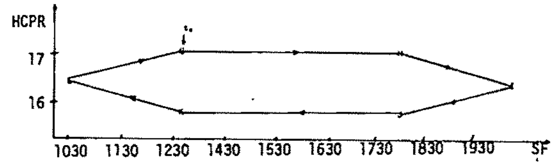



Figure 10. Six-months cycle

that at $t_o$ the two cycles are not in the same cycle phase. Again there is a clockwise motion.

Some important points should be observed about the one-year cycle depicted in Figure 9. First, it appears that the ellipse's major axis has been rotated approximately 90 degrees. This fact leads to the following proposition: Where the four- and two-year cycles are oscillating more widely on the price, the one-year cycle is oscillating widely about the quantity with a minor variation on the prices. This conclusion indicates the impact of the national business cycle and other outside forces operating in the longer run versus the internal industry supply-demand interaction operating in the shorter run. Secondly, the motion direction is counterclockwise, perhaps violating in this particular case both theories—Cobweb and harmonic motion—advocating an opposite direction. It is beyond the scope of this paper to establish a theory explaining this phenomenon.

Nevertheless, a few alternative or complimentary explanations may be provocative enough to encourage more investigation. (a) Pork is a storable item for periods of less than a year determined by taste and the fixed variable costs of inventory maintenance. Assuming a clockwise motion on the inventory control process with relation to prices, then a counterclockwise one-year cycle will adequately refill the storage. (b) Production cost differentials throughout the year coupled with consumer preference differentials throughout the year may be unrelated to each other and may bring about this motion. (c) After viewing the shorter cycles below, which again possess a clockwise motion, one may wonder if the one-year cycle is a kind of "overtone" caused by the industry and crucial to keeping balance

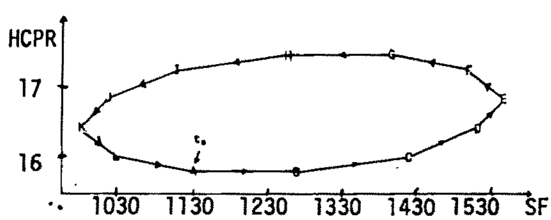



Figure 9. One-year cycle

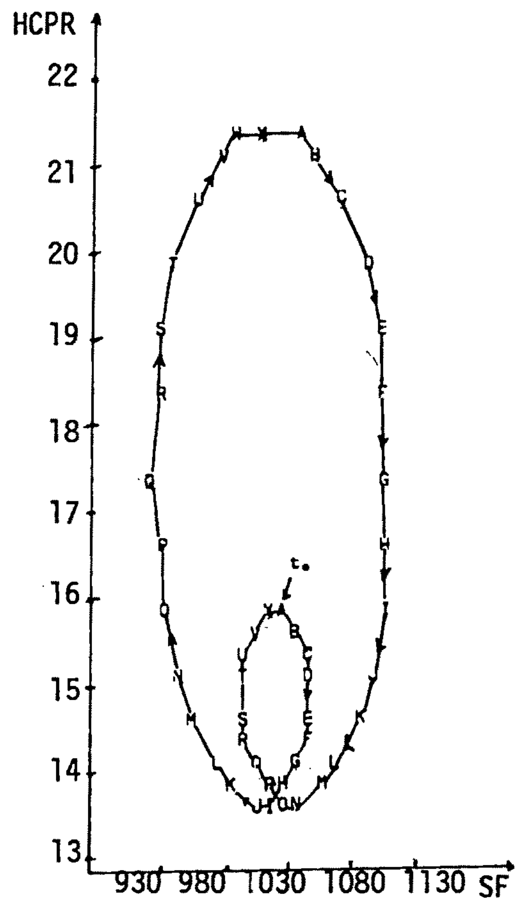



Figure 11. Four and two-years cycles

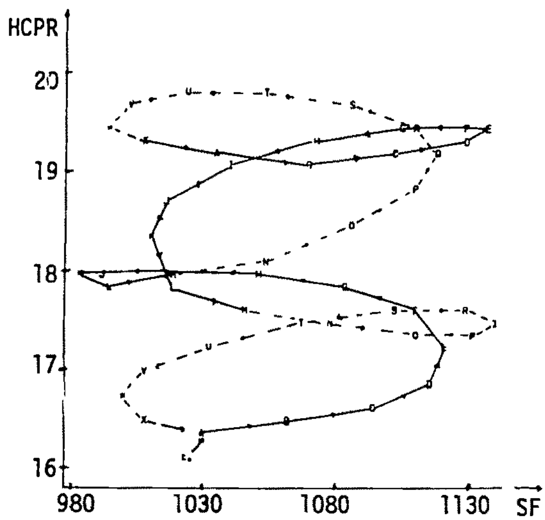



Figure 12. Four and one-year cycles

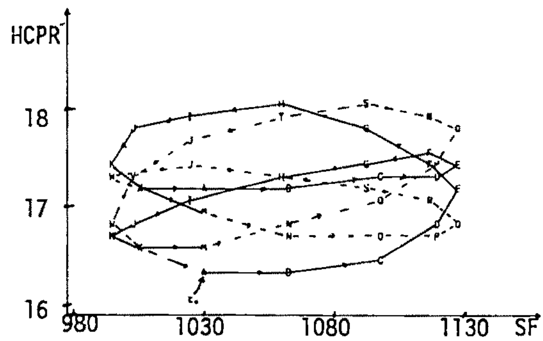



Figure 14. One-year and 16-months cycles

among the other cycles. (d) With regard to consumer preference for pork, such phenomena as holidays, religious customs, and weather conditions (with annual periodicity) may contradict the long run elasticity expectations. Figure 9 shows an ellipse which is very clearly the one-year cycle but with a counterclockwise motion. The sharp variation on the quantity axis represents the two-peak, spring and fall farrowing with a relatively low farrowing in the summer and winter. Figure 10 illustrates the six-months cycle that is similar to Figure 9 but with a clockwise motion.

Figures 11–16 present the combined motions of two or more cycles. In the discussion to follow, perhaps it will help to keep in mind that as the total cycle is decomposed, interest lies in analyzing the relative frequencies of its components. Figure 11 is a combination of the four- and the two-year cycles. It shows two years of rapidly changing prices and two years of slowly changing prices along with corresponding quantities. With reference to the Cobweb and Harmonic Theories that propose either a two-year or a four-year cycle respectively, this figure demonstrates that both frequencies are required for an adequate explanation of the true cyclical behavior. Figure 12 is another excellent example of the combination of high and low frequency cycles. As the four-year cycle moves slowly to complete its time path in 48 months, shown as a smooth ellipse in Figure 7, it is seriously disturbed by the aggressive one-year cycle which also determines the motions' direction. Figure 13 shows the interaction of the one- and the two-year cycles which represents roughly one half the time behavior shown in Figure 12. An interesting reaction between the one-year and 16-months cycles is revealed in Figure 14. The impact of the 16-months cycle can be interpreted as a vertical rotation of the axis of the one-year ellipse within the four-year period. Essentially, it allows for the different slopes and modifications of each of the one-year cycles.

The high speed, short run cycles presented in Figure 15 emphasize the relatively oscillatory quantity behavior versus the moderate variation on prices in a one-year period. All of the long and intermediate run cycles are depicted in Figure 16. Here the same pattern as shown in Figure 6 is generally discovered. This expresses the estimated time path in the hog production industry where it is found that in two out of every four years, low hog prices prevail with the up-

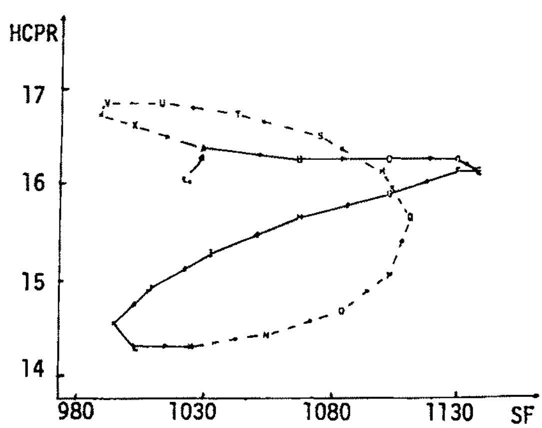



Figure 13. Two and one-year cycles

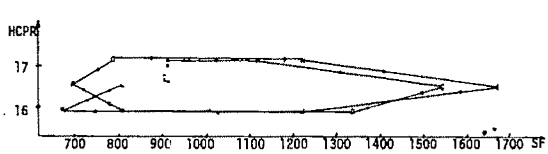



Figure 15. Six, four, and three months cycles

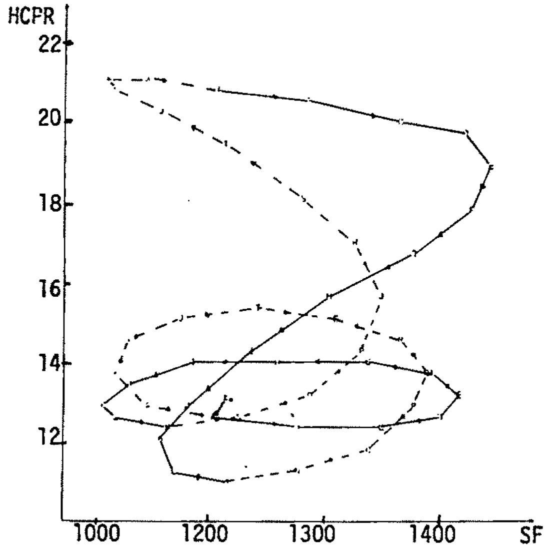



**Figure 16. Four, two, one-year, and 16-months cycles**

turn and downturn taking one year each, tracing out two different paths. Particularly noteworthy is the observation that the downturn path is to the right of the supply curve in the case of expansion-contraction when substantial variable and fixed costs are involved in the decision making process.[10]

## Distributed Lag Estimation

Having statistically tested and accepted the existence of the combined series of cycles operating simultaneously, it is appropriate to show a linkage with the Cobweb model. According to the Cobweb model the completion of the cycle by a price lag equal to one-half the cycle period is to be expected. Furthermore, these lagged price ratios are expected to be statistically significant in explaining the Sows Farrowing variable. To test this hypothesis, a modified special case of the Koyck distributed lag model [7] was chosen. Let the structural equation express the SF as a linear function[11] of lagged price ratio variables as follows:

$$(8)\quad SF_t = \beta_o + \beta_1 HCPR_{t-1} + \ldots + \beta_i HCPR_{t-i} + e_{SF};\ i = 1, 2, \ldots, 50$$

where $\beta_o, \beta_1, \ldots \beta_i$ are constants to be estimated by least squares procedure.[12] $i$ goes from 1 to 50 to include 48 months delay corresponding to an eight-year cycle which has been statistically rejected by the frequency analysis but is standing again for a test. $e_{SF}$ is the disturbance term.

Applying a least-square stepwise-add routine [11], the results summarized in Table 3 are reached. The variable selection procedure was to add a variable if it was the best candidate and was significantly different from zero at the 5 percent level and to reject any variable previously included if it was no longer significant at the 10 percent level.[13] The time lag in the price ratio was set at four time-units (months) earlier than the sows farrowing time lag to correspond to the approximate time of breeding. Since the time of

[10] For an excellent treatment of the supply response under the condition of resource fixity, see [6].

[11] Even though other mathematical transformations may be more suitable, linear transformation was used here for simplicity.

[12] Applying ordinary least-squares on (8) may result in violations of the assumptions underlying multiple regressions using least-squares techniques, but the interest here lies in the relative size, the sign, and standard error of the coefficients. Therefore, heteroscedasticity, if it occurs, should not rule out least-squares procedure. The correlation coefficients among the independent variables, after the deletion process was completed, did not exceed 0.40.

[13] Such a situation may occur when a single independent variable previously selected becomes insignificant where a combination of later variables better "explains" the dependent variable and is linearly correlated with the single independent variable.

Table 3. Sows Farrowing estimation using lagged hog-corn price ratio, by LS, stepwise add method

| Independent Variable | Time Lag About Breeding (i) | Regression Coefficient | Standard Error of Coefficient | $t$-value | Significance Level | Cycle Period $= 2 \times$ (i) Selected | Hypothesized |
|---|---|---|---|---|---|---|---|
| Constant | — | 101.2 | 219.1 | 4.6 | $<0.0005$ | — | — |
| HCPR(t-5) | 1 | −92.3 | 13.3 | −6.9 | $<0.0005$ | 2 | 3 |
| HCPR(t-7) | 3 | 135.1 | 15.3 | 8.8 | $<0.0005$ | 6 | 6 |
| HCPR(t-10) | 6 | −19.8 | 11.6 | −1.7 | 0.091 | 12 | 12 |
| HCPR(t-17) | 13 | −82.2 | 11.9 | −6.9 | $<0.0005$ | 26 | 24 |
| HCPR(t-20) | 16 | 93.2 | 12.0 | 7.8 | $<0.0005$ | 32 | — |
| HCPR(t-29) | 25 | −32.1 | 8.3 | 3.8 | $<0.0005$ | 50 | 48 |

breeding may be distributed throughout the month, it is safe to conclude that the actual farrowing could occur in a ± one month deviation from the time hypothesized. With this in mind Table 3 gives a great deal of support to the Cobweb theory behind each individual cycle. The first lagged price should be considered in agreement with the hypothesized lags simply because there are no fractions of lag units, so the 1.5 lag is unobtainable. The next two time lags are exactly in agreement; the fourth and sixth are within the range allowed for the time range in actual farrowing. The 32-months cycle "estimated" here is exactly twice the 16-month cycle in the frequency analysis above, which may be simply because it is not compatible with a 48-month cycle. The 8-month cycle, although initially selected at an earlier step, disappeared after losing its level of significance in the stepwise-add routine by the dominance of other cycles.

## Summary and Conclusion

A theory of the hog cycle as a Multi-Frequency Cobweb model, or as a linear combination of decomposable hog cycles, has been presented. This model reflects an integrated multi-frequency decision process resulting from the feedback of the production response to the price ratio signal through fixed multiple production lags. Decisions with long, intermediate, and short run implications are continuously made, and their impacts are projected to future decisions and production process. The equilibrium and disequilibrium positions are under continuous attempts to adjust because of the existence of many simultaneous decision-response relationships. During periods of expansion, the hog producer builds or remodels facilities and invests in a larger breeding herd. These investments have different time spans in their consequences. During periods of contraction the producer still bears the consequences of the ong term investment made during expansion. This may explain the four-year cycle.

A traditional Cobweb adjustment process may involve the two year cycle. The 16-month cycle may be the producers' evaluation of the profit prospects based on the relation between the corn supply of the current year and that of the previous year. The short run cycles of 6, 4, and 3 months may be explained by seasonal, weather, and market signals coupled with capacity utilization of building and equipment subject to biological and technical constraints. Interactions with inventory control management affect the short cycles much more than they do the long ones [8].

Theoretically the model incorporates three basic models: the Cobweb Theorem, the Harmonic Motion, and the Distributed Lags Model. As was seen, each was unable to explain satisfactorily the supply response of the hog industry when used individually. The Cobweb and Harmonic Motion models are essentially special cases of the presented model.

Econometrically, the Fourier Series appears to be an excellent mathematical representation of a dynamic disequilibrium phenomenon. Inertia of adjustments is preserved as in cases where overshooting a target is gradually corrected. The characteristic of correction coming from previous motions preserves properties of macro-production systems with distributed delay behavior. The orthogonality property of the Fourier Series, although not completely achieved, contributed to the equality of the estimation and permitted frequency analysis and decomposition of the cycle. The Multi-Frequency Cobweb Model with some relaxation of assumptions may be appropriate in many other production cycles where integrated multiple frequencies decision making processes are simultaneously undertaken.

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# Industrial Growth in the Tennessee Valley Region, 1959 to 1968*

CHARLES B. GARRISON

Shift analysis and the technique of entropy indicate an increase in the strength of rural and small-town counties competing with urban areas for manufacturing employment during the study period. Increase in the strength of the most rural counties apparently was confined to labor-oriented industries, but small towns and small cities were successful in attracting industries of varying orientations. Despite the rapid rate of industrialization, rural counties experienced slow or negative population growth; this is attributed to the absence of sizeable employment multiplier effects and to offsetting employment declines in extractive industries. The implication is that considerable potential exists for further rural industrialization.

*Key words:* rural dispersal; manufacturing; entropy; employment multiplier; labor-intensive.

THE EXTENT to which rural areas in the United States are becoming more attractive as locations for manufacturing industry is a subject of considerable current interest. As traditional employment opportunities in agriculture and the extractive industries have declined sharply, rural areas have experienced heavy outmigration and population losses. But more recently there has developed evidence that rural areas in some parts of the country are experiencing something of a rebirth due to industrial development [1, 2, 4, 5, 10]. In this paper the extent to which rural counties have shared in the growth of manufacturing in one particular part of the country, the Tennessee Valley Region, is examined. The period of study is 1959 to 1968, and the data used are county employment and earnings by industry as provided to the Tennessee Valley Authority by the relevant state employment security agencies.

The study also makes an effort to identify the particular types of manufacturing activity that have tended to locate in the region's rural counties. In particular, the hypothesis is formulated that those industries defined as "labor-intensive" are more widely dispersed within the region than manufacturing in total, and hence the attractiveness of the region's counties to labor-oriented manufacturing activity is substantially different from the attractiveness of the counties in regard to other types of manufacturing. The concept of entropy, which seems to have arisen in statistical thermodynamics and has received its greatest impetus from the work of Shannon [13] in communications theory, is introduced as a means of investigating this and related hypotheses. Further it is contended here that entropy and especially its counterpart measure numbers-equivalent are of great value to those interested in the geographic distribution of economic activity in that they provide a simple yet comprehensive index by which geographic concentrations may be measured, compared, and analyzed.

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## The Tennessee Valley Experience

The Tennessee Valley Region as defined here includes 194 counties: all 95 counties in Tennessee and 99 counties in six neighboring states (see Fig. 1). Haren [6] has classified the region as "predominantly rural" and has used it as an example of rural success in attracting new manufacturing plants in the 1960s. However, there are seven metropolitan areas (Standard Metropolitan Statistical Areas or SMSA's) in the region (Knoxville, Chattanooga, Nashville, Memphis, Asheville, Gadsden, and Huntsville). These SMSA's contain 13 counties (pre-1973 definition), and an additional 42 counties have urban populations in excess of 10,000. The remaining 139 counties are classified here as either rural or small-town as defined in Table 1. The designations of Table 1 are used in examining the degree to which non-metropolitan areas, and especially rural and small-town counties, were successful in capturing an increasing share of manufacturing activity in the region during the period 1959 to 1968. (Obviously further breakdowns could be accomplished; thus of the 72 small-town counties, 30 have urban populations ranging from 2,500 to 4,999, and 42 have urban populations of 5,000 to 9,999.)

In Table 2 it is seen that the rural and small-town counties did indeed have higher rates of growth in manufacturing employment than did the urban and metropolitan counties; as a

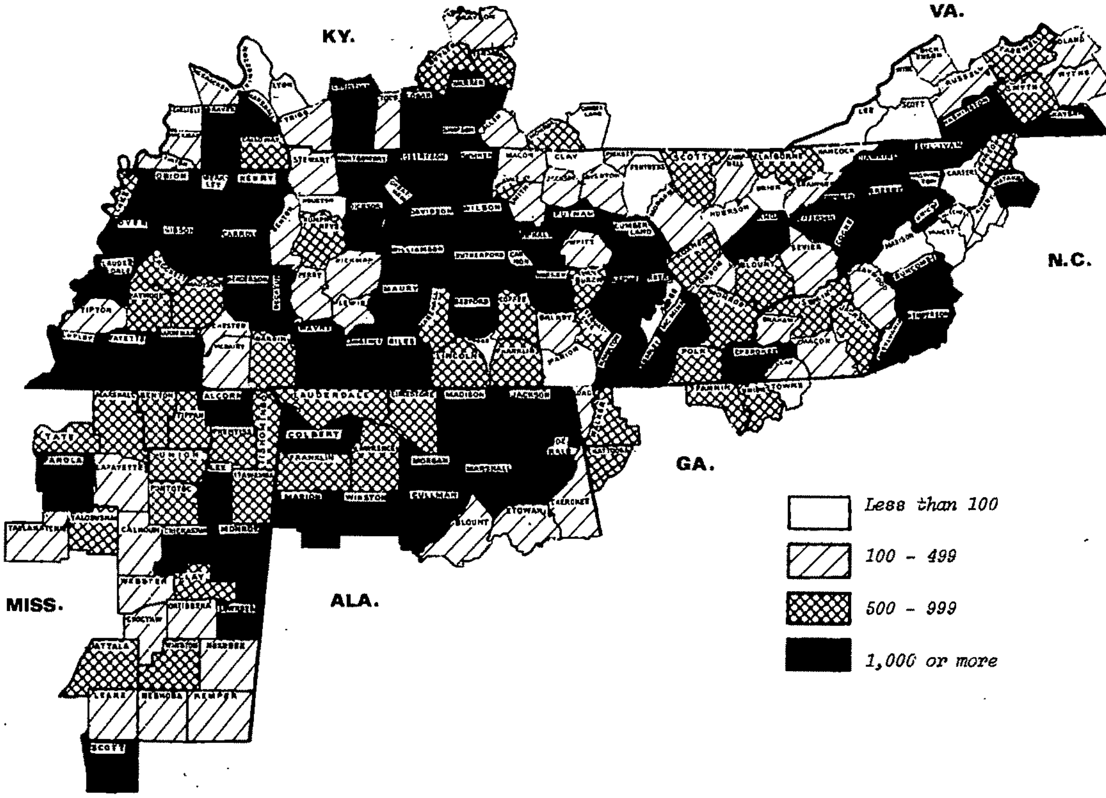


Figure 1. Change in manufacturing employment, Tennessee Valley Region, 1959 to 1968

matter of fact, the more rural the area the greater the growth rate. In terms of employment shares, the rural and small-town counties, which together accounted for only 23.7 percent of the region's total manufacturing employment in 1959, accounted for 39.1 percent of the increase of 232.3 thousand employees during the period, with the result that their 1968 share of employment was 29.0 percent. For those industries identified as labor-intensive, the performance of the two most rural groups was even more impressive, as they accounted for 56.8 percent of the employment increase of 73.7 thousand to raise their share from 37.1 percent in 1959 to 42.4 percent in 1968. The bulk of labor-intensive employment in the region was accounted for by the apparel, textile, furniture, wood products, and leather industries. Labor-intensive industries are defined as those in the top quartile of manufacturing industries ranked according to wages per dollar of value added, where industries are classified at the three-digit S.I.C. (Standard Industrial Classification) level. Since there are 100 industries at the three-digit level, 25 are identified as labor-intensive. Any scheme to identify labor-intensive or labor-oriented industries, that is, those for which an abundant supply of relatively unskilled labor is an important location factor, will contain an element of arbitrariness. Other definitions could be used as well, and in fact some of the analysis later in this paper makes use of an alternative categorization, "low-wage" industries.

**Table 1. Distribution of counties by degree of urbanization, Tennessee Valley Region**

| Designation of County | Urban Population, 1970 | Number of Counties | |
|---|---|---|---|
| Nonmetropolitan | | | 181 |
| Entirely Rural | 0 | 67 | |
| Small Town | 2,500– 9,999 | 71 | |
| Small City | 10,000–24,999 | 28 | |
| Urban | 25,000 or More | 15 | |
| Metropolitan | | | 13 |
| Total | | | 194 |

The performance of the county groups may be analyzed also from the point of view of manufacturing earnings (not shown here), perhaps more useful than employment as an indicator

Table 2. Growth in manufacturing employment, Tennessee Valley Region, 1959 to 1968

| Type of County | 1959 | 1968 | Change: Number | Change: Rate[b] |
|---|---|---|---|---|
| | Thousand | Thousand | Thousand | Percent |
| | | Labor-Intensive Manufacturing[a] | | |
| Nonmetropolitan | 135.5 | 201.9 | 66.4 | 4.5 |
| Entirely Rural | 22.1 | 40.2 | 18.1 | 6.9 |
| Small Town | 52.5 | 76.3 | 23.8 | 4.2 |
| Small City | 37.8 | 53.0 | 15.2 | 3.8 |
| Urban | 23.1 | 32.4 | 9.3 | 3.8 |
| Metropolitan | 65.4 | 72.7 | 7.3 | 1.2 |
| Total | 200.9[c] | 274.6 | 73.7 | 3.5 |
| | | Total Manufacturing | | |
| Nonmetropolitan | 254.2 | 430.1 | 175.9 | 6.0 |
| Entirely Rural | 28.8 | 55.6 | 26.8 | 7.6 |
| Small Town | 78.1 | 142.1 | 64.0 | 6.9 |
| Small City | 74.2 | 130.5 | 56.3 | 6.5 |
| Urban | 73.1 | 101.9 | 28.8 | 3.8 |
| Metropolitan | 196.3 | 252.7 | 56.4 | 2.8 |
| Total | 450.5 | 682.8 | 232.3 | 4.7 |

[a] Defined as the top quartile of manufacturing industries ranked according to wages per dollar of value added, where industries are classified at the three-digit S.I.C. (Standard Industrial Classification) level. Calculated by the author from county and industry employment data provided by the Tennessee Valley Authority. All employees covered by unemployment insurance are included in the TVA data.
[b] Rate of growth compounded annually.
[c] Detail may not add to total due to rounding.

of an area's economic base. The two most rural groups again exhibit higher growth rates, but their *share* of the increase during the period is somewhat less. This is to be expected, however, at least to the extent that employment existing at the beginning of the period was greater in the urban areas and accounted for a part of the earnings increases. Further, there is evidence that wage levels are higher in the urban areas; for example, wages per man-hour in the region's apparel industry in 1964 amounted to $1.44 in metropolitan areas and $1.36 in nonmetropolitan areas [16] ("selected" areas only).

The success of the rural and small-town areas is even more pronounced when national growth and industry mix forces are removed from the analysis. Shift analysis provides a means for removing these forces; it is a technique whereby that portion of the total growth in an industry's employment (or sales, or payroll) in an area (here, a county) which is due to a "differential shift" may be identified [12]. The differential shift arises if employment in a county in a particular industry is expanding more rapidly in that county than in the nation as a whole. Then county groups which exhibit net upward differential shifts over time may be said to have improved their competitive position relative to other parts of the country in attracting this type of economic activity.[1]

The shift analysis, which is summarized in Table 3, indicates that most employment growth in the rural and small-town counties consisted of competitive gains (74.2 thousand of total growth of 90.8 thousand jobs for the two groups combined), while much of the growth in the urban and metropolitan areas may be attributed to national growth and industry mix forces affecting those industries already located there at the beginning of the study period. Most growth in the small-city group, 42.1 of 56.3 thousand jobs, also is attributed to competitive

[1] According to [12], let

$E_{ij}$ = employment in the $i$th industry and the $j$th county in the initial time period,
$E^*_{ij}$ = the same in the terminal time period,
$E_{i.}$ = national employment in the $i$th industry.

Then the differential shift for the county is

$$S_d = \Sigma_i \left( E^*_{ij} - \frac{E^*_{i.}}{E_{i.}} E_{ij} \right).$$

Table 3. Shift analysis: differential or "competitive" gains in manufacturing employment, Tennessee Valley Region, 1959 to 1968[a]

| Type of County | Labor-Intensive | | Capital-Intensive[b] | | Total Manufacturing | |
|---|---|---|---|---|---|---|
| | Thousand | | | | | |
| Nonmetropolitan | | 47.7 | | 14.5 | | 128.1 |
| Entirely Rural | 15.2 | | 0.4 | | 22.7 | |
| Small Town | 16.4 | | 6.8 | | 51.5 | |
| Small City | 10.0 | | 6.0 | | 42.1 | |
| Urban | 6.0 | | 1.3 | | 11.8 | |
| Metropolitan | | 0.6 | | 8.9 | | 28.9 |
| Total | | 48.3 | | 23.4 | | 157.0 |

[a] The competitive effects are calculated at the three-digit S.I.C. level of industry disaggregation, with 1959 as the base year.

[b] Defined as the bottom quartile of manufacturing industries ranked according to wages per dollar of value added, where industries are classified at the three-digit level.

gains. The greater competitive gains in the more rural areas indicate greater availability of location advantages relevant to manufacturing activity. In particular, competitive gains in labor-intensive industries were mainly accounted for by the two most rural groups, with the metropolitan counties contributing only about 1 percent of competitive gains. A limitation to the types of industries which perceived location advantages in the entirely rural counties is suggested by the fact that competitive gains were virtually zero for those industries identified as "capital-intensive." (Major employers in the capital-intensive group were included in the chemicals; food; printing; stone, clay, and glass; and primary metals industries.) However, the small-town (and small-city) counties apparently were attractive to virtually all types of industries, including those intermediate between the labor-intensive and capital-intensive classifications. Within the small-town group, the counties with urban populations of 5,000 to 9,999 accounted for 5.0 thousand of the group's 6.8 thousand competitive employment gain in capital-intensive industries.

## A Measure of Dispersal

In this section the concept of entropy is introduced as a means of providing an overall *index* of the geographic concentration of manufacturing or of certain types of manufacturing industries. The particular advantage of entropy is that it permits the analyst to consider all counties in the region rather than relying upon, say, the share of employment accounted for by the metropolitan counties as a measure of concentration. It is shown here that entropy and its related measure, the numbers-equivalent, are especially useful in measuring changes in concentration over time or differences in concentration between different sets of industries.

First the analogy is drawn between entropy in communication theory, in an industrial system, and in a regional system. In communication theory entropy measures the degree of uncertainty as to the message which the system might transmit. Horowitz [7, 8, 9] has drawn the analogy with an industrial system, where entropy measures the degree of uncertainty as to the firm which might be frequented by a customer chosen at random. He suggests that the greater this uncertainty, the greater the degree of competition in the industry. In this paper the analogy is carried a step further: the greater the entropy in a regional system, the greater the degree of competition among the counties in the region in attracting industry, and therefore the more dispersed within the region are those location factors considered important by manufacturers. See Paulson and Garrison [11].

Consider a set of $k$ categories (counties) $C_1, C_2, \ldots, C_k$ and a random sample of size $n$ (employees) taken at time $t$. Each employee of the sample is assigned to one of the counties $C_i$ with fixed probability $p_i > 0$, $i = 1, 2, \ldots k$, $\Sigma p_i = 1$, and a total of $n_i$ employees are located in county $C_i$. Then the entropy of the regional system is defined by

$$(1) \qquad h = -\Sigma n_i/n \; ln \; n_i/n$$

where $ln$ denotes natural logarithms and $n_i/n$ might be taken as an estimate of $p_i$, the relative ability of the $i$th county to attract manufacturing industries. If all employment is located in

the $i$th county, then $n_i/n = 1$ and $h = 0$; that is, there is no uncertainty in the regional system. If two counties share equally in the region's employment, then $n_i/n = ½$ and

(2) $h = -1/2 \ ln\ 1/2 - 1/2 \ ln\ 1/2 = ln\ 2.$

That is, the greater the number of counties sharing (equally) in the region's employment, the greater the degree of uncertainty or dispersal and the higher the value of $h$. It can be shown in fact that $h$ reaches a maximum when the $k$ counties are equally strong in attracting employment, that is, when

(3) $$h = -k(1/k) \ ln\ (1/k) = -ln\ 1 + ln\ k = ln\ k.$$

Unfortunately the economic interpretation of an $h$ value of say 4.2131 or 3.969 is not at all obvious. Horowitz has suggested the use of the counterpart measure

(4) $$f = \exp h,$$

the number of equal-sized categories necessary to generate the observed entropy, as a measure of concentration or dispersal which is subject to a rather straightforward interpretation. He has applied the numbers-equivalent concept to the measurement of seller concentration in an industrial system, where for example $f = 1$ might be interpreted as a monopoly; that is, there would be no uncertainty as to which firm would be patronized by a customer chosen at random. An industry in which the number of equal-sized firms $f < 10$ might be characterized as "concentrated" (that is, an oligopoly) while if $f > 500$, the industry exhibits little concentration and in terms of number of sellers would approach the perfectly competitive model.[2] In the present case the numbers-equivalent may be interpreted as the number of equal-sized *counties* (in employment); a low $f$ indicates an industry or type of industry which is concentrated in area within the region while a high numbers-equivalent indicates one which tends to be areally dispersed. In particular, it follows from the discussion of maximum entropy above that the maximum number of equal-sized counties is 194; that is, maximum uncertainty in the regional system corresponds to $f = 194$. Also, relative entropy $g = h/ln\ k = h/ln\ 194$ reaches a maximum of $g = 1.0$ when $h = ln\ 194 =$ maximum.

[2] In Horowitz' analysis $n_i/n$ represents the $i$th firm's share of industry sales (or of some alternate measure of firm strength such as the share of industry employment).

Table 4. **Entropy $h$, number of equal-sized counties $f$, and relative entropy $g$ for the 194-county Tennessee Valley Region**

| | | 1959 | 1968 |
|---|---|---|---|
| Employment[a] | | | |
| Total Manufacturing | $h$ | 4.2131 | 4.4575 |
| | $f$ | 68 | 86 |
| | $g$ | .7998 | .8464 |
| Labor-Intensive Manufacturing | $h$ | 4.4696 | 4.6516 |
| | $f$ | 87 | 105 |
| | $g$ | .8485 | .8830 |
| Capital-Intensive Manufacturing | $h$ | 3.3969 | 3.5294 |
| | $f$ | 30 | 34 |
| | $g$ | .6448 | .6700 |
| Earnings[a] | | | |
| Total Manufacturing | $h$ | 3.9008 | 4.2079 |
| | $f$ | 49 | 67 |
| | $g$ | .7405 | .7988 |
| Labor-Intensive Manufacturing | $h$ | 4.2879 | 4.5071 |
| | $f$ | 73 | 91 |
| | $g$ | .8140 | .8556 |
| Capital-Intensive Manufacturing | $h$ | 3.1102 | 3.3190 |
| | $f$ | 22 | 28 |
| | $g$ | .5904 | .6301 |
| | | 1960 | 1970 |
| Population | $h$ | 4.6345 | 4.5793 |
| | $f$ | 103 | 97 |
| | $g$ | .8798 | .8693 |

[a] Labor-intensive and capital-intensive industries are defined at the three-digit S.I.C. level. Earnings are for the first quarter of the indicated years; their coverage and source are the same as for employment.

Table 4 gives values for entropy $h$, numbers-equivalent $f$ and relative entropy $g$ (the extent to which maximum dispersal is attained among the counties in the region) by type of manufacturing. The numbers-equivalents $f$ are especially useful in providing a convenient index of the geographic dispersal of manufacturing and especially of labor-intensive manufacturing, which was observed for the period 1959 to 1968 in the preceding section. Table 5 provides the same index for manufacturing groupings according to wage level. The low-wage industries might be considered those in which an abundant labor supply is the most important location factor, and again it is observed that the greatest dispersal—for any given point in time—occurs in those industries. Thus the county-equivalent analysis indicates that the strength of the region's counties is substantially different in attracting labor-oriented manufacturing as opposed to non-labor-oriented manufacturing. In par-

**Table 5. Numbers-equivalent analysis of manufacturing employment for the 194-county Tennessee Valley Region**

| Average Weekly Earnings (1963) and Manufacturing Group | Number of Equal-Sized Counties $f$ | |
|---|---|---|
| | 1959 | 1968 |
| $120 or Higher | 16 | 27 |
| 19-Ordnance | | |
| 29-Petroleum, Coal Products | | |
| 33-Primary Metals | | |
| 37-Transportation Equipment | | |
| $105–119 | 23 | 32 |
| 26-Paper, Allied | | |
| 27-Printing, Publishing | | |
| 28-Chemicals | | |
| 34-Fabricated Metals | | |
| 35-Nonelectrical Machinery | | |
| $ 90–104 | 35 | 53 |
| 20-Food, Kindred Products | | |
| 30-Rubber, Miscellaneous Plastics | | |
| 32-Stone, Clay, Glass | | |
| 36-Electrical Machinery | | |
| 38-Instruments | | |
| $ 75–89 | 65 | 73 |
| 24-Lumber, Wood Products | | |
| 25-Furniture, Fixtures | | |
| 39-Miscellaneous | | |
| Less than $75 | 91 | 111 |
| 21-Tobacco | | |
| 22-Textiles | | |
| 23-Apparel | | |
| 31-Leathers | | |

ticular, the location advantages important to the former group are more dispersed, and there is a greater degree of "competition" in attracting these industries. Further, the increase in the $f$ values over time indicates an increase in geographic dispersal for industries of *all* wage levels or *all* types of orientation. This indicates that location advantages relevant to *all* types of manufacturing have become more dispersed over time and suggests a more general increase in competitiveness among the region's counties.

The entropy technique is useful not only in providing an overall index of dispersal over time but also, through its decomposition properties, in analyzing the nature of such a dispersal; see Thiel [15]. Consider that, if the industry categories of Table 5 are compressed into the two categories "high-wage" and "low-wage," it is possible that the increase in $f$ over time for low-wage industries was due either to an increase in employment in the rural and small-town groups but confined to those counties in which plants were already located, or to further dispersal within the small-city and urban classes. Calculations of numbers-equivalent *within* separate groups (sets) reveals that in fact neither of these two possible explanations is relevant (Table 6). The increase in $f$ values *within* the rural and small-town sets indicates dispersal of employment over time to counties which had relatively little employment at the beginning of the period, while the virtually constant numbers-equivalents within the small-city and urban sets indicates no such dispersal.

Decomposition of entropy into its between-set and within-set components also is useful in explaining the pattern of dispersal over time. Write $k$ for the number of counties in the region and indicate their employment shares by $y_i = n_i/n$, $i = 1, \ldots, k$, $\Sigma y_i = 1$, $y_i \geqq 0$, where $n$ is the total employment in the region and $n_i$ is the employment in the $i$th county. Then entropy may be written as

$$h(y) = -\Sigma y_i \ln y_i. \tag{5}$$

**Table 6. Numbers-equivalents within separate sets, manufacturing employment in the 194-county Tennessee Valley Region**

| | Number of Equal Sized Counties $f$ | | |
|---|---|---|---|
| | Maximum $f$ | 1959 | 1968 |
| | High-Wage Industries ($\geqslant$ $90 per week)[a] | | |
| Entirely Rural | 67 | 17 | 27 |
| Small Town | 71 | 34 | 45 |
| Small City | 28 | 18 | 21 |
| Urban | 15 | 10 | 11 |
| Metropolitan | 13 | 8 | 8 |
| Total | 194 | 35 | 52 |
| | Low-Wage Industries (< $90 per week)[a] | | |
| Entirely Rural | 67 | 31 | 42 |
| Small Town | 71 | 54 | 59 |
| Small City | 28 | 22 | 23 |
| Urban | 15 | 13 | 13 |
| Metropolitan | 13 | 9 | 8 |
| Total | 194 | 95 | 114 |

[a] Industries are classified according to average weekly wage prevailing in 1963.

Further, if the counties are combined into $G$ sets, the employment share of set $S_g$ is then

$$(6) \qquad Y_g = \sum_{i \epsilon S_g} y_i \qquad g = 1, \ldots, G.$$

Then the entropy $h(y)$ may be disaggregated as follows:

$$(7) \qquad h(y) = h_o(y) + \sum_{g=1}^{G} Y_g h_g(y),$$

where

$$(8) \qquad h_o(y) = -\sum_{g=1}^{G} Y_g \ln Y_g$$

is the between-set entropy, and

$$(9) \qquad h_g(y) = -\sum_{i \epsilon S_g} \frac{y_i}{Y_g} \ln \frac{y_i}{Y_g}$$

is the entropy within $S_g$.

This disaggregation of entropy, where $G = 5$, is carried out in Table 7 and enables one to compare the low-wage and high-wage industries as to the nature of their geographic dispersal over time. Note that for both types of industries, the within-set entropy increased more than the between-set entropy over time; that is, there was a greater tendency toward a uniform distribution *within* the county groups than *between* the groups. For low-wage industries, the rural and to a lesser extent the small-town groups "accounted for" all the positive increase in within-set entropy. But for high-wage industries, the rural group was not very important as a component of within-set entropy; rather, the small-town and small-city sets were responsible for the increase in within-set entropy. This is due to the fact that the components of the within-set entropy, as shown in (7), are the *weighted* within-set entropies, where the weights are the employment shares of the sets. These shares are shown in Table 8; the rural set's share of high-wage employment is small, and it could not be regarded as a major force influencing dispersal over time. This is true despite the fact that, given the (small) employment in the rural set, there was a tendency toward a more uniform distribution within the set; this tendency is shown by the (unweighted) within-set numbers equivalents in Table 6. Thus the disaggregation of entropy indicates an increase in the strength of both the rural and small-town groups in attracting low-wage industries. But for higher wage industries the analysis indicates very little increase in the strength of rural counties; the increase in competitiveness in the region in attracting these industries is due largely to the

**Table 7. Decomposition of entropy for manufacturing employment, Tennessee Valley Region**

| | 1959 | | 1968 | | Change | |
|---|---|---|---|---|---|---|
| **High-Wage Industries (≥ \$90 per week)[a]** | | | | | | |
| Within-Set Entropy | | 2.3406[b] | | 2.5982 | | 0.2576 |
| Entirely Rural | 0.0633 | | 0.0781 | | 0.0148 | |
| Small Town | 0.3160 | | 0.5599 | | 0.2439 | |
| Small City | 0.3726 | | 0.5417 | | 0.1691 | |
| Urban | 0.4786 | | 0.4420 | | −0.0366 | |
| Metropolitan | 1.1100 | | 0.9765 | | −0.1335 | |
| Between-Set Entropy | | 1.2229 | | 1.3472 | | 0.1243 |
| Total Entropy | | 3.5635 | | 3.9454 | | 0.3819 |
| **Low-Wage Industries (< \$90 per week)[a]** | | | | | | |
| Within-Set Entropy | | 3.0299 | | 3.1854 | | 0.1555 |
| Entirely Rural | 0.3852 | | 0.5930 | | 0.2078 | |
| Small Town | 1.0800 | | 1.1799 | | 0.0999 | |
| Small City | 0.6378 | | 0.6514 | | 0.0127 | |
| Urban | 0.2671 | | 0.2557 | | −0.0114 | |
| Metropolitan | 0.6597 | | 0.5054 | | −0.1543 | |
| Between-Set Entropy | | 1.5248 | | 1.5527 | | 0.0279 |
| Total Entropy | | 4.5547 | | 4.7380 | | 0.1833 |

[a] Industries are classified according to average weekly wage prevailing in 1963.
[b] Figures shown for the separate sets are the *weighted* within-set entropies.

Table 8. Shares of manufacturing employment and employment change, Tennessee Valley Region

| | Share | | | | | |
|---|---|---|---|---|---|---|
| | 1959 | | 1968 | | Change | |
| Type of County | Percent | | | | | |
| High-Wage Industries (⩾ $90 per week)[a] | | | | | | |
| Nonmetropolitan | | 45.2 | | 53.5 | | 67.0 |
| Entirely Rural | 2.2 | | 2.4 | | 2.6 | |
| Small Town | 9.0 | | 14.8 | | 24.1 | |
| Small City | 12.9 | | 17.8 | | 25.9 | |
| Urban | 21.1 | | 18.5 | | 14.4 | |
| Metropolitan | | 54.8 | | 46.5 | | 33.0 |
| Total | | 100.0 | | 100.0 | | 100.0 |
| Low-Wage Industries (< $90 per week)[a] | | | | | | |
| Nonmetropolitan | | 69.5 | | 75.7 | | 91.2 |
| Entirely Rural | 11.2 | | 15.9 | | 27.4 | |
| Small Town | 27.1 | | 28.9 | | 33.6 | |
| Small City | 20.6 | | 20.8 | | 21.3 | |
| Urban | 10.6 | | 10.1 | | 8.8 | |
| Metropolitan | | 30.5 | | 24.3 | | 8.8 |
| Total | | 100.0 | | 100.0 | | 100.0 |

[a] Industries are classified according to average weekly wage prevailing in 1963.

strength of the small-town and small-city counties. (The negative changes for the metropolitan and urban groups shown in Table 7 are due not to an increase in geographic concentration within these groups but to their reduced shares, which causes them to account for less of the total within-set entropy in 1968 than in 1959).

### Income and Employment Multipliers

How successful has the rural dispersal of manufacturing in the Tennessee Valley Region been in arresting the decline of rural communities? In particular, has industrialization reversed the population outmigration of previous decades? Entropy and county-equivalent analysis indicate that, in spite of manufacturing dispersal, the region's population became *more* concentrated from 1960 to 1970 (Table 4). As a matter of fact, the more urban the county grouping, the greater the increase in population, in both numbers and rate of growth (Table 9); it is interesting to note that, at the end of the 1960's, labor-oriented manufacturing in the region was more dispersed than was population,

Table 9. Population growth in the Tennessee Valley Region

| | Population | | | Change | | Percent Change | |
|---|---|---|---|---|---|---|---|
| | 1950 | 1960 | 1970 | 50–60 | 60–70 | 50–60 | 60–70 |
| Type of County | Thousand | | | Thousand | | | |
| Nonmetropolitan | 4,018 | 3,939 | 4,150 | −78 | 214 | −1.9 | 5.4 |
| Entirely Rural | 893 | 752 | 738 | −140 | −14 | −15.7 | −1.9 |
| Small Town | 1,492 | 1,380 | 1,428 | −112 | 48 | −7.5 | 3.5 |
| Small City | 896 | 956 | 1,029 | 60 | 76 | 6.7 | 7.9 |
| Urban | 737 | 851 | 955 | 114 | 104 | 15.5 | 12.2 |
| Metropolitan | 1,774 | 2,123 | 2,436 | 348 | 313 | 19.6 | 14.8 |
| Total | 5,792 | 6,062 | 6,586 | 270 | 527 | 4.7 | 8.6 |

Sources: Calculated from [17].

as shown in Tables 4 and 5.) Migration data provide more specific evidence of the inability of manufacturing growth to provide adequate job opportunities (Table 10). Out-migration was especially heavy in the young adult groups, reaching rates of 60 percent in many agricultural and mining counties. Obviously a major explanation of continued outmigration in the region is the decline of employment opportunities in the traditional rural pursuits of agriculture, wood products, and mining. (However, it should be noted that *income* from these activities, the relevant measure in identifying the rural economic base, declined only slightly in real terms during the period; and farm income actually increased in several important agricultural areas such as west Tennessee and northeast Mississippi, as did mining income in the coal counties of southwest Virginia.) Further, despite an impressive growth *rate* in manufacturing in the rural and small-town counties, the combined absolute increase in payrolls was still somewhat smaller than in the remaining (combined) groups.

Finally, it is likely that a major explanation of the population change pattern is found in the lower income and employment multipliers in the more rural counties. One would expect the community income multiplier to vary directly with city size, due to a greater variety of goods and services in larger cities and therefore smaller leakages from the local income stream. But in addition, it appears that in rural counties the employment multiplier effect is considerably smaller than the income effect, due to previously existing underutilization of labor and capital in the local retail and services sector of rural economies. Thus a study of five Kentucky counties in which the population of the largest town ranged from 1,000 to 5,000 found that the ratio of basic income to nonbasic employment existing in 1958 was a great deal lower than the *increase* in basic income "required" per *additional* nonbasic job in the period 1958 to 1963 [3]. While it is not possible here to distinguish accurately between basic and nonbasic employment in the region, a rough approximation suggests that indeed nonbasic or locally-oriented employment opportunities in rural and small-town counties failed to grow at a rate commensurate with the growth of manufacturing employment. Thus while the rural and small-town groups accounted for 39.1 percent of manufacturing growth during the period, they accounted for only 21.1 percent of nonbasic growth (Table 11). Further, the combined nonbasic employment share of the two groups declined from 1960 to 1970. Much the same pattern characterizes a major nonbasic subsector, the trade and service industries. For purposes of comparison, manufacturing employment in the region increased by 232.3 thousand (from 1959 to 1968), while nonbasic employment increased by 363.1 thousand (from 1960 to 1970), including 249.7 thousand in trade and services. Since much of the new industry in rural and small-town counties relies upon local labor (and therefore draws its employees from existing residents) and since relatively few new nonbasic jobs are likely to be created, it is not surprising that these counties experienced only modest population increases or actual declines.

**Table 10. Provisional net migration, Tennessee Valley Region, 1960 to 1970**

| Age in 1970 | Total | Male | Female |
|---|---|---|---|
| 0– 9 | −18,703 | −7,884 | −10,819 |
| 10–19 | −9,159 | −2,133 | −7,026 |
| 20–29 | −191,208 | −116,618 | −74,590 |
| 30–39 | 4,269 | 3,452 | 817 |
| 40–64 | 44,956 | 26,568 | 18,388 |
| 65 and Over | 26,681 | 12,848 | 13,833 |
| Total | −143,164 | −83,767 | −59,397 |
| Nonmetropolitan | −179,135 | | |
| Metropolitan | 35,971 | | |

Source: Compiled from individual county migration figures provided by the Center for Business and Economic Research, The University of Tennessee. Race-specific migration data not available.

The population performance of the rural and small-town groups does, however, represent an improvement over that of the two preceding decades; the rural and small-town groups combined had a population gain of 34,000 during the 1960's as opposed to a loss of 252,000 during the 1950's. Hansen [5] has identified 74 "turnaround" counties in the region, that is, counties which gained population in the 1960's after losing in the 1950's or counties which gained in both decades but grew rapidly in the 1960's after relative stagnation in the 1950's. Obviously the extent to which outmigration has declined may be attributed in large part to the growth of the manufacturing sector of the local economic base, with a relatively small role attributable to the multiplier effect. The difficulty of overcoming large employment declines in other sectors of the economic base is illustrated

Table 11. Shares of employment and employment change, selected nonmanufacturing industries, Tennessee Valley Region[a]

| Type of County | Share | | | | | |
|---|---|---|---|---|---|---|
| | 1960 | | 1970 | | Change | |
| | Percent | | | | | |
| Nonbasic Industries[b] | | | | | | |
| Nonmetropolitan | | 48.6 | | 49.2 | | 51.5 |
| Entirely Rural | 6.7 | | 6.8 | | 7.3 | |
| Small Town | 15.1 | | 14.8 | | 13.8 | |
| Small City | 11.4 | | 11.4 | | 11.5 | |
| Urban | 15.5 | | 16.2 | | 18.9 | |
| Metropolitan | | 51.4 | | 50.8 | | 48.5 |
| Total | | 100.0 | | 100.0 | | 100.0 |
| Trade and Services | | | | | | |
| Nonmetropolitan | | 50.6 | | 50.3 | | 49.2 |
| Entirely Rural | 6.6 | | 6.6 | | 6.5 | |
| Small Town | 15.5 | | 14.9 | | 12.9 | |
| Small City | 12.4 | | 12.1 | | 11.2 | |
| Urban | 16.2 | | 16.7 | | 18.6 | |
| Metropolitan | | 49.4 | | 49.7 | | 50.8 |
| Total | | 100.0 | | 100.0 | | 100.0 |

Sources: Calculated from [17].
[a] Employment by county of residence.
[b] Includes all industries except manufacturing, mining, and agriculture.

by the fact that, in the rural and small-town groups, only three of the 13 "cotton counties" and none of the eight "coal counties" in the region gained in population. For the rural and small-town groups as a whole, a majority of the counties showed increases.

## Summary

Rural and small-town counties in the Tennessee Valley Region experienced considerably more rapid rates of growth in manufacturing during the period 1959 to 1968 than did urban counties. Most of the growth in the rural group (those with an urban population of less than 2,500) was in labor-oriented or low-wage industries, but the small-town and small-city counties (with urban populations of 2,500–9,999 and 10,000–24,000 respectively) were successful in attracting industries of varying orientations, including those with high wage levels. Shift analysis and the technique of entropy indicate that rural and small-town growth was due in large part to an increase in the underlying strength or attractiveness of these areas in competing with urban areas for manufacturing activity, although the increase in the strength of the rural group apparently was confined to labor-oriented industries.

Despite the more rapid rates of manufacturing growth in rural areas, urban and metropolitan counties had faster population growth rates. Slow or negative rural population growth is attributable in part to offseting employment declines in nonmanufacturing sectors of basic economic activity, including agriculture, forestry, and mining, and in part to the likelihood of rather small employment multiplier effects associated with manufacturing growth. The implication is that, despite the fact that the region has become more industrialized than the nation as a whole, considerable potential exists for further manufacturing growth.

Entropy $h$ and the related measure numbers-equivalent $f$ are introduced as a means of measuring the geographic concentration of economic activity. This technique is capable of providing a single index of concentration (or dispersal) which takes into account *all* the geographic categories (here, counties) in the region and, when presented as the numbers-equivalent $f$, is subject to a straight-forward interpretation. Further, the decomposition properties of entropy enable it to explain the exact nature of a tendency toward dispersal (or concentration) over time. For these reasons its use is commended to regional analysts.

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# A Utility Approach to the Valuation of Recreational and Aesthetic Experiences*

J. A. Sinden

**A method for valuing extra-market benefits is proposed and tested. The method rests on the empirical derivation of utility functions and indifference maps. Demand schedules were obtained from the indifference maps to provide specific benefit values. The method is compared to the conventional travel-cost method for valuing recreational benefits. It is argued that the utility approach is conceptually superior. Also, the utility data comprised both the benefit values from the indifference maps and direct survey responses as surrogates for utility. These data proved better predictors of consumption than the usual travel-cost variables.**

***Key words:*** **utility; indifference maps; extra-market benefits; recreation valuation; travel-cost method.**

The valuation of recreational and aesthetic experiences is difficult because these goods are not exchanged in a regular market place. Several methods have been proposed to place dollar values on such extra-market benefits. At issue is the appropriateness of the tools to measure the true benefit, or consumer's surplus, of the particular experience. It is argued here that the consumer's surplus can and should be measured by a direct approach to individual utilities rather than by an indirect estimate of aggregative utility.

The argument proceeds as follows. The travel cost procedure is the most widespread method for valuing recreational experiences. It gives indirect estimates of aggregate utility. This procedure is briefly reviewed first. Then methods for measuring the intensity of individual preferences, or tastes, are developed and tested. Next the travel cost procedure is modified to remove the assumption of constant tastes. In light of this examination of the conventional procedure, a different valuation method is proposed and tested. It involves the experimental determination of indifference maps with a model of utility estimation and is a direct approach to estimating individual utilities. Finally, the relative merits of the two methods are discussed.

## The Travel Cost Method in Review

The travel cost procedure is based on empirical demand functions of the form

$$(1) \qquad Q_r = f(p, I, Z_1 \ldots Z_n)$$

where $Q_r$ is the quantity of a specific recreational activity, $p$ is the travel cost as a proxy for price, $I$ is income, and $Z_1 \ldots Z_n$ are other explanatory variables. A demand curve is derived by plotting the quantities consumed at various travel costs, against the travel cost. The levels of the other variables are fixed at their means.

Consumer's surplus values are calculated from the area under the demand curve. The limitations of this valuation method have been discussed at length elsewhere [for example, 1, 3, 8]. However, two basic assumptions are repeated here since the present study attempts to modify one of them and to provide an alternative approach to valuation thus removing the need for the other. In the travel cost method, the consumer's surplus of the total experience of user $j$ is assumed to be equal to the costs of the most distant user less the costs of $j$ himself. Use of cross-sectional data therefore leads to indirect measures of consumer's surplus. This first assumption implies, *inter alia,* that all users who incur the same travel cost will, on average, consume the same quantity of the specific recreation activity. This implication is in fact the second assumption, namely that tastes are constant. More rigorously defined, the assumption is that persons in different distance zones would take the same quantity of recreation at the same monetary costs.

Three points concerning the travel-cost method are taken up in this paper. They involve the assumption of constant tastes, the relative importance of the independent explanatory vari-

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ables, and the debate on the aggregation procedure. A modification for taste is offered by explicitly including a variable for taste, or intensity of preferences, in the demand function.

## Intensity of Preferences for Environmental Experiences

### An economic model

The Hicksian concept of compensating variation of consumer's surplus provides the basis for the model. A photo-choice game was developed from the model to give numerical estimates of intensity of preferences for a given recreation activity in a specific environment. Consider a subject with a given recreation budget for his marginal costs. Consider, too, that he has a choice of five environments (A to E) in which to pursue his chosen activity. One environment (A) was selected as the base environment.[1] The subject was then asked the following question: What is the maximum amount that you would just be willing to pay to go to B (or C, D or E) rather than go to A? This willingness to pay measures the subject's intensity of preference for recreation in one environment over the base environment.

### The field survey

A survey of 189 groups of recreationists in part of the South Santiam Valley of the Cascade Mountains of Oregon was completed in the summer of 1972 [9]. The recreationists were mainly in family groups. The groups were stratified by recreation activity and site. They were sampled with random starts within each stratum. Data were collected for each group on their socioeconomic characteristics, recreation activities over the last 12 months, and on numerical measures of preferences. The questions to scale intensity of preference were framed as in the economic model in terms of willingness to pay extra monetary costs to go to one environment rather than another. Two other measures of relative preference were obtained, namely willingness to pay extra travel time and extra travel distance. Thus, in the field the "decision-maker" in each group was presented pictures of five environments (A to E). He was asked the maximum that he was just willing to pay (as measured by costs, hours, and miles) to visit the most preferred environment over environment A.[2] In each case, the time of the visit was specified as the weekend after the interview. The recreation activity during the visit, the group membership, and local conditions were specified as identical to those of the present visit.

### Testing the preference measurements

Consistency and relevance of the preference measures were examined by including them separately in a demand function and testing for significance. The function was of the form

$$Q_r = f(X_1 \dots X_{10}) \tag{2}$$

after the general travel cost model of equation (1). Specific variables were as follows:

$Q_r$ = the number of hours of a specific recreation activity ($r$) per family member during the 12 months prior to the interview,

$X_1$ = distance (miles) from home to site, as the proxy for price, transformed into natural logarithms,

$X_2$ = total taxable family income ($) per year transformed into natural logarithms,

$X_3$ = age (years) of household head transformed into natural logarithms,

$X_4$ = days of paid vacation per year per household head,

$X_5$ = hours of beach recreation per family member during the previous 12 months,

$X_6$ = hours of camping per family member at a specific state park in the valley during the last year,

$X_7$ = hours of boating per family member on reservoirs in the valley during the last year,

$X_8$ = the ratio of hours of city to country recreation per family member during the last year,

$X_9$ = willingness to pay extra hours of travel to reach the most preferred environment (B, C, D, or E) rather than stay at the base environment (A), and

$X_{10}$ = $X_9$ divided by total time (hours) devoted to the specific recreation activity per trip.

[1] In the field photo-choice game, 98 percent of the subjects nominated the environment "A" as their least preferred environment.

[2] Data on two further measures of preference were collected in the survey [9]. They were the rank order (1 to 5) and a scaling (0 to 100) of the subject's expected utility of recreation in each environment. These were not relevant as measures of intensity of preference in the present analysis. Interpersonal comparisons of preferences are impossible because these data lack a common quantitative unit such as hours or dollars. In any case these two measures did not prove to be statistically significant in explaining variations in $Q_r$.

**Table 1. Estimated elasticities from 10 recreation demand functions: dependent variables $Q_1$ to $Q_{10}$**

| Recreation[a] Activities | At the Free-Flowing River | | | | | | At Adjacent Reservoirs | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Camping | | | Day Use | | Fishing | Camping | | Day Use | Boating |
| Independent Variable[b] | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | $Q_5$ | $Q_6$ | $Q_7$ | $Q_8$ | $Q_9$ | $Q_{10}$ |
| $X_1$ Distance | −0.29 | −0.76 | | −0.54 | | −0.31 | −0.45 | −0.98 | −0.40 | −0.34 |
| $X_2$ Income | | | | | | +0.64 | | | | |
| $X_3$ Age | | | | | | | −1.61 | | | |
| $X_4$ Days Vacation | −0.06 | | | +0.31 | | | | | +0.42 | |
| $X_5$ Beach Recreation | | | | | | | | | +0.13 | +0.39 |
| $X_6$ Camping CSP | | | | | | +2.42 | | | −0.18 | |
| $X_7$ Boating | | | | | | +0.02 | | | | |
| $X_8$ City/Country Recreation | | | | −0.25 | | | | | | −0.20 |
| $X_9$ Intensity of Preference | +0.34 | | +1.18 | | +1.08 | | +1.38 | | +0.92 | +0.76 |
| $X_{10}$ $(X_9)$/Total Hours per Visit | | −0.60 | −0.14 | −0.68 | −1.06 | | −0.32 | | | |
| Number of Observations | 13 | 11 | 16 | 18 | 15 | 37 | 11 | 9 | 21 | 38 |
| $R^2$ % | 78 | 43 | 76 | 45 | 45 | 39 | 81 | 24 | 65 | 50 |

[a] The camping activities on the river refer to the following populations; $Q_1$—income less than \$11,000, origin less than 350 miles; $Q_2$—income more than \$11,000, origin less than 350 miles; and $Q_3$—origin more than 350 miles. Day use activities refer to those from nearer than 350 miles ($Q_4$) and those from more than 350 miles ($Q_5$). Camping activities on two adjacent reservoirs refer to users with incomes less than \$11,000 ($Q_7$) and with incomes more than \$11,000 ($Q_8$).

[b] Independent variables were considered significant if their $t$ value exceeded the standard $t$ value at the 10 percent probability level. In fact, 21 of the 31 values were significant at the 5 percent level or better.

The logarithmic transformations on the first three independent variables, namely distance, income, and age, followed the usual *a priori* hypotheses. The reasoning was supported by the positive regression results. Least squares regression methods were used to estimate the constant and coefficients in the structural equations. Multicollinearity did not prove a difficulty. Elasticities from the 10 demand functions are listed in Table 1. These are the only data from the original study [9] which are essential to this stage of the analysis.

Of the three measures of the intensity of preference, only one proved significant. This was willingness to pay specified as extra hours of travel time ($X_9$). No consistent relationship could be found between either of the other measures of preference and the dependent variable $Q_r$. Thus, willingness to pay as extra dollar costs was not significant.[3] Another preference variable, $X_{10}$, is included in Table 1. This is $X_9$, intensity of preference as extra time costs, divided by the total time for travel and on-site recreation for a single visit. The variable ($X_{10}$) was significant in five of the 10 regressions. It was significant in two regressions where $X_9$ was not significant.

The variable $X_9$ measures the intensity with which the individual prefers one environment over another for a specific recreation activity. It is, therefore, a surrogate for the functional form of the utility function which relates the preference for the activity in the two environments. Inclusion of this variable provides the modification of the travel cost procedure to allow for differences in preference or taste. The con-
the application of actual utility functions to
sistent significance of the variable encourages
benefit valuation.

## Whose preference data?

The first questions in the field interviews were on home town facts and family details. They acted as a filter from which the interviewer selected the "apparent decision-maker" in the

[3] This leads me to question other studies which draw conclusions from similar dollar measures on willingness to pay without validating the results for consistency.

family. The photo-choice questions to measure intensity of preferences were directed to this person. Games for mapping indifference curves and determining utility functions were also directed to this person. There was good statistical correlation between preferences ($X_9$ and $X_{10}$ in Table 1) and use ($Q_r$), and between the benefit values of the utility approach (Table 6) and use. These tests provide some support for the method of selecting the decision-maker.

## Consumer's Surplus Values from the Travel Cost Method

### The assumption of constant tastes

As noted above, the travel cost method assumes that persons in different distance zones take the same quantity of recreation at the same monetary costs. Inclusion of socio-economic variables, such as income ($X_2$) and age ($X_3$), together with variables for alternative recreation activities ($X_5$, $X_6$, $X_7$ and $X_8$) partially removes this assumption.[4] But in the 10 functions of the survey (see Table 1), these variables ($X_2$ to $X_8$) were only rarely significant. On the other hand, the preference variables ($X_9$ and $X_{10}$) were consistently significant. These two variables were specifically structured to measure the intensity of an individual's preference (or taste) for one environment over another. Thus their inclusion explicitly removes the assumption of constant tastes.

### Relative importance of the independent variables

Data from the 10 demand functions provided several reasons to consider both preferences and distance in a model of benefit valuation. First, the elasticities in Table 1 show that, except for $Q_2$, the quantity of use is more responsive to the preference variables ($X_9$ and $X_{10}$) than to distance ($X_1$). The $t$ test data on the regression coefficients led to the same conclusion. Second, distance and preference (as $X_9$ or $X_{10}$) are the two most powerful explanatory variables. A stepwise regression program was used to build the demand functions. The six functions which included both distance and intensity of preference also included several socioeconomic variables. But the first two variables to be introduced were always distance and one of the preference variables ($X_9$ or $X_{10}$). These two together accounted for some two-thirds of the $R^2$ value of each regression. Finally, there is some evidence that distance ($X_1$) and preference ($X_9$ and $X_{10}$) act independently. For example, the signs on $X_1$ and $X_9$ differ, and the simple correlation coefficients between $X_1$ and $X_9$, and between $X_1$ and $X_{10}$ were less than 20 percent. Inclusion of the preference variables in the demand function is one way of including both taste and distance in benefit evaluation. Another way is the utility approach presented below.

### The aggregation debate

Use of statistical demand functions for valuation and other work in recreation has been criticized. Seckler [6, 7] has argued that the slope and position of the demand curve could be a function more of income than of the utility of the recreational experience itself. Stoevener and Brown [10, 11] showed that the aggregation of separate demand curves for income groups may well be necessary to adjust for the effects of income. But they questioned one of Seckler's conclusions, namely that the "true" adjusted aggregate curve is more elastic than the computed aggregate curve.[5] Data from the 10 demand functions permit an examination of three of the issues in this debate. First, is willingness to pay, as measured by the area under the demand curve, correlated with income? If there is a positive correlation, does the extra willingness to pay of higher income persons reflect a lower utility of income rather than a higher utility of use? Finally, do the data suggest that the true aggregate curve, adjusted for income, is more or less elastic than the computed aggregate curve?

Income could be related to quantity of use in at least two ways. First, the response to distance ($D$), as the proxy for price, may be the

[4] The error term in the regression equations of the demand functions may also accommodate some of the variation in taste.

[5] The term "true" refers here to the aggregate demand curve derived by the horizontal summation of individual demand curves. In the debate the term "correct" was used in this sense. In the example of the present paper a population of 37 persons was divided into three groups. The true aggregate curve is therefore the horizontal summation of individual curves for each of these three groups. This procedure was used to correct for the possible effects of income on demand. In contrast the computed aggregate curve was derived in a different theoretical manner. The mean per person demand function was first computed using the data from all 37 persons. The mean demand curve was determined, and this was horizontally summed 37 times to give the computed aggregate curve. In the present paper, the following hypothesis was tested: that because of the different theoretical formulation, the two aggregate curves have different slopes and intercepts.

same at any income level ($I$). Then the following regression model is applicable:

$$(3) \qquad Q_r = a - b_1 D + b_2 I$$

where $a$ is the regression constant, and $b_1$ and $b_2$ are the regression coefficients. Seckler [6, p. 488] hypothesized that this model may sometimes be relevant. Alternatively, the response to distance may differ at different income levels. A different model,

$$(4) \qquad Q_r = a - bD,$$

would now apply and would be built for each income group. Seckler [7, p. 148 and Fig. 1] suggested that a relationship similar to, but not identical with, equation (4) may exist. There may be still other relationships between income, use, and distance. But in the present study it was postulated that the data would follow either equation (3) or equation (4). Despite a review of pertinent literature, no *a priori* reasoning could be developed to suggest that one equation would be more relevant than the other; thus both models were estimated.

The results provide some support for Seckler's underlying thesis on the first issue. There was indeed a positive correlation between income and use, in those functions where income in any way affected use. High income persons were willing to pay more, that is travel greater distances and incur greater travel expenses, than low income persons. Income was a significant determinant of use in two activities, namely camping and

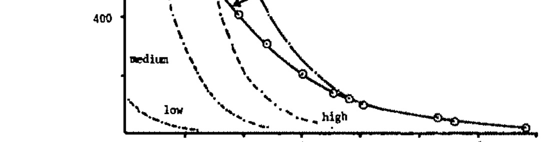


**Figure 1. The aggregation of demand curves, with curves for three separate income groups (low, medium, and high-dashed lines), and two aggregate curves (firm lines)**

fishing. The results for fishing ($Q_6$) followed equation (3), where increases in income were associated with shifts of the demand curve to the right. The two camping activities, differentiated by site, followed equation (4). The data were sub-divided into two income groups ($Q_1$ and $Q_2$, and $Q_7$ and $Q_8$). In both of these camping activities the elasticities on distance were greater with the higher income groups ($Q_2$ and $Q_8$). Higher income persons therefore have a greater, negative, response to a given increase in distance. When the position of the demand curve was considered, as well as its slope, the curve for the high income group was to the right of that of the low income group in both camping activities.[6] In the other activities, namely day use ($Q_4$, $Q_5$, $Q_9$), boating ($Q_{10}$), and campers on the river from distant sources ($Q_3$), income did not affect use in either of the two postulated ways.

A utility function for income was not derived for any subject in the present study. Thus no rigorous test of the second issue is possible. It is not possible to state specifically that increased willingness to pay is due to a lower marginal utility of money of high income persons rather than a high utility of use. The only related empirical evidence is conflicting. The actual marginal costs of travel and recreation of all the activities are small, both in an absolute sense and relative to actual incomes. Thus it seems intuitively reasonable to invoke the argument that marginal utility of money is constant between persons, and per person, over the actual range of expenditures. However, the income variable for fishing ($Q_6$) is a logarithmic transformation. Successive increments in income have less and less effect on the quantity of fishing. But this is not rigorous proof that higher income persons derive a lower utility from the marginal recreation dollar. Further, distance is the proxy for price in the present study. Thus the elasticities of Table 1 show the response to changes in distance and not to changes in monetary costs. This approximation does not affect the discussion on the statistical correlation between income and use (the first issue) or on the relative

[6] At distances greater than 250 miles this relationship is ambiguous, due partly to the logarithmic transformation of distance and partly to the paucity of observations of these distances. However, at a distance of 250 miles, the quantity taken at both sites is less than 25 hours of camping per family member per year. This figure would preclude an overnight stay. Thus the schedule for distances greater than 250 miles does not provide a rigorous test of the issue.

shapes of the true and adjusted aggregate curves derived from statistical functions (the third issue). But it does affect the debate on this second issue. Again, no rigorous test is possible.

The third issue concerned the relative elasticities of the computed aggregate curve and the true aggregate curve, adjusted for income. As noted above, the income variable was only significant in the fishing and camping activities so that the adjustment was only considered for these functions. For camping, the data are already analyzed in income groups after equation (4). Thus the aggregate curve, derived from the two separate income groups, would already be adjusted for income. However, the fishing function followed equation (3) where response to distance proved to be constant for all incomes. Therefore the debate on elasticities is relevant only to this activity.

The computed aggregate curve for fishing was derived in the following, conventional manner. The mean of all significant variables, including income but except distance, was noted and multiplied by the respective regression coefficients. These products were added to the regression constant to give a "reduced" regression. Finally, quantities of use for all 37 persons were calculated from the reduced regression model for given distances to give the computed aggregate curve (Fig. 1).

The true aggregate curve was calculated as follows. The sample of 37 persons was divided into three groups by income. The "low" group comprised the lowest third of the incomes. Mean income was calculated for the group, and, along with all other variables except distance, incorporated as before into the regression constant. The demand schedule for the group was then calculated by varying distance to give the quantity taken. The "high" group comprised the highest third of the sample by income. The demand schedule for this group was calculated as for the "low" group. Finally, the remaining third of the sample were placed in the "medium" group and a demand schedule was calculated for these persons.[7] The true aggregate demand curve was obtained by aggregating the schedules of these three groups.[8]

[7] The mean income of the "medium" group differed slightly from the mean of all 37 persons. The resulting differences in quantities taken disappeared when quantities were rounded to the nearest 100 hours.

[8] The use of three groups assumes that the sample is comprised of only three types of person, each with a different income. This assumption eased the calculation without detracting from the test of the particular issue.

The computed and true aggregate curves and the curves for the three income groups are given in Figure 1. These results show that, for a regression model which follows equation (3), the true aggregate curve has the same elasticity as the computed curve over a portion of its range and is less elastic over the remainder of its range. This result supports Stoevener and Brown [10, 11]. The result could have been derived directly from equation (3). The illustrative example that has been presented here provides an empirical explanation of this issue.

### The consumer's surplus values

Distance is the proxy for price in the present study. Thus the area under the demand curve is in a (distance-times-hours) unit. In the travel cost method such units have been converted to monetary estimates by multiplying by a constant travel cost per mile. Consumer's surplus values are then derived by deducting the total visit cost (or price) from the total benefit (total area under the curve). This method was applied to day use at the park. For persons who came from less than 350 miles ($Q_4$ in Table 1), the consumer's surplus value was 36 cents per man-day.[9] The utility approach to benefit valuation, which is developed in the next section, provides a different method for valuing recreational benefits. The particular activity, which is the example for this approach, is again day use at the state park.

## Indifference Mapping for Consumer's Surplus Values

Data from the 10 demand functions provide evidence to justify a different approach to valuation. The preference variable $X_9$ is a surrogate for the form of the utility function relating recreation in various environments. The consistent significance of this variable suggests that

[9] The total area under the curve for $Q_4$ up to the mean quantity of use (19.5 hours per family member) was 0.9 units. The unit refers to (100 miles $\times$ 10 hours). The 200 mile round trip, at 35 cents per gallon, 20 miles per gallon and no other variable expenses, cost \$3.5. The unit was therefore valued at \$3.5. The 10 hour unit was adjusted to a 12 hour day trip to compare with the utility approach. Thus the total benefit of 0.9 units is "worth" \$2.6 or (\$3.5 $\times$ 0.9 $\times$ 10/12). The marginal user at the mean quantity of use, had a round-trip journey of 70 miles. At 20 miles per gallon and 35 cents per gallon, his round trip costs were \$1.2 per 12 hour visit. Total expenses for the mean quantity of use are therefore (\$1.2 $\times$ 19.5/12) or \$2.0. The consumer's surplus, as the area between the demand curve and the price, is (\$2.6 — \$2.0) or 60 cents for 19.5 hours. This is 36 cents per 12 hour visit per person.

the utility function itself could provide valid measures of the trade-offs between activities. Also, the significance of $X_9$ indicates that the subjects could give meaningful answers to questions which involved choices between times spent in recreation activities. Together with the independence and importance of both the distance and preference variables, these reasons justified the experimental determination of utility functions themselves and the associated indifference maps. The functions were derived with the Ramsey model of utility estimation. Consumer's surplus values were then derived from demand curves that were calculated directly from the indifference maps.

### The Ramsey model of utility estimation

The Ramsey model can be presented formally as a one-person game (Table 2). The subject is asked to choose between two prospects each of which is a two-element probability combination. There are four possible outcomes, $a$ to $d$. The actual outcome depends on the prospect selected and on the event which actually occurs. There are a range of models of utility estimation [2]. The special feature of the Ramsey model is that both probabilities are specified as 0.5 [5, p. 179]. Although the von Neumann-Morgenstern model is frequently used, Officer and Halter [4] report that the Ramsey model proved preferable in field tests of farmers' decisions in drought conditions. The Ramsey model was preferable because the neutral probabilities of 0.5 cause no bias due to preferences for different probabilities. For the same reason the subjects can derive no utility from gambling, and so again there is no bias in the results.

In the present study, the Ramsey model was adapted to determine total utility curves for the consumption of a specific recreation commodity. The formal principles are as follows. Outcomes $a$ and $c$ (Table 2) are defined as quantities (days) of the particular recreation commodity under consideration. Outcomes $b$ and $d$ are specified as quantities (days) of two other recreation activities. Then by direct questioning, the quantity of outcome $c$ is varied until the subject is indifferent between the two prospects. Since prospect I is equal to prospect II in preference, and since the probabilities are set at 0.5,

$$(5)\quad 0.5(U(a))+0.5(U(b)) = 0.5(U(c))+0.5(U(d)),$$

where $U$ stands for utility. Multiplying through by 2.0,

$$(6)\quad U(a)+U(b)=U(c)+U(d).$$

Transposing, to have outcomes $a$ and $c$ on the same side, and arbitrarily setting the utility interval $(U(b)-U(d))$ at 5 utiles,

$$(7)\quad U(b)-U(d)=U(c)-U(a)=5\text{ utiles.}$$

A second game is played in which outcomes $b$ and $d$ remain as before. But now the value of outcome $c$ at indifference is taken from position (iii) in game 1 and placed in position (i) in game 2. A new outcome, $e$, is placed in position (iii) in game 2. Outcome $e$ is again a quantity (days) of the recreation commodity under consideration. Table 3 shows an actual example of game 1. An actual example of game 2 is shown in Table 4 and illustrates the introduction of outcome $e$. By direct questioning as before, the value of $e$, in position (iii) in game 2, is found at indifference. Thus, after equations (5), (6), and (7),

$$(8)\quad U(b)-U(d)=U(e)-U(c)=5\text{ utiles.}$$

A base utility level is now arbitrarily set. Let $U(a)=0$. Thus, from equations (7) and (8), three points are known on a total utility curve for the particular commodity. These points are, $U(a)=0$, $U(c)=5$, and $U(e)=10$. Further points on this total utility curve are found by playing further games. Just as the second game was based on the first, successive games place the value from position (iii)

Table 2. The formal Ramsey model for utility estimation[a]

| Probability of Occurrence | Prospect I | Prospect II |
|---|---|---|
| 0.5 | (i) $a$ | (iii) $c$ |
| 0.5 | (ii) $b$ | (iv) $d$ |

[a] The notations (i) to (iv) refer to positions in the matrix. The values $a$ to $d$ refer to potential outcomes.

Table 3. The Ramsey model of utility estimation—game 1 for subject 2[a]

| Probability | Prospect I | Prospect II |
|---|---|---|
| 0.5 | (i) 0 days *CSP* | (iii) $n$ days *CSP* |
| 0.5 | (ii) 1 day *PL* | (iv) 0 days *CL* |

[a] The value of $n$ at indifference is determined by direct questioning in the game. Let it be 0.5 days in game 1.

**Table 4. The Ramsey model of utility estimation—game 2 for subject 2[a]**

| Probability | Prospect I | Prospect II |
|---|---|---|
| 0.5 | (i) 0.5 days *CSP* | (iii) *n* days *CSP* |
| 0.5 | (ii) 1 day *PL* | (iv) 0 days *CL* |

[a] The value in position (i) in this game is taken from the value in (iii) at indifference in game 1. It is therefore 0.5 days *CSP*. The value of *n* at indifference in game 2 is again found by indifference. Let it be 1.25 days.

in the previous (or first) game into position (i) in the new (or second) game. Then by direct questioning the value of the outcome in the new position (iii) is varied until the subject is indifferent between the prospects. Outcomes *b* and *d* remain fixed throughout the games for each separate total utility curve. They provide the fixed utility interval.

In the empirical application which follows, this model and procedure is used to determine a single total utility curve for days of recreation at a specific state park in Oregon. Then by varying the quantity of outcome *b*, in position (ii), a family of total utility curves (Fig. 2) is

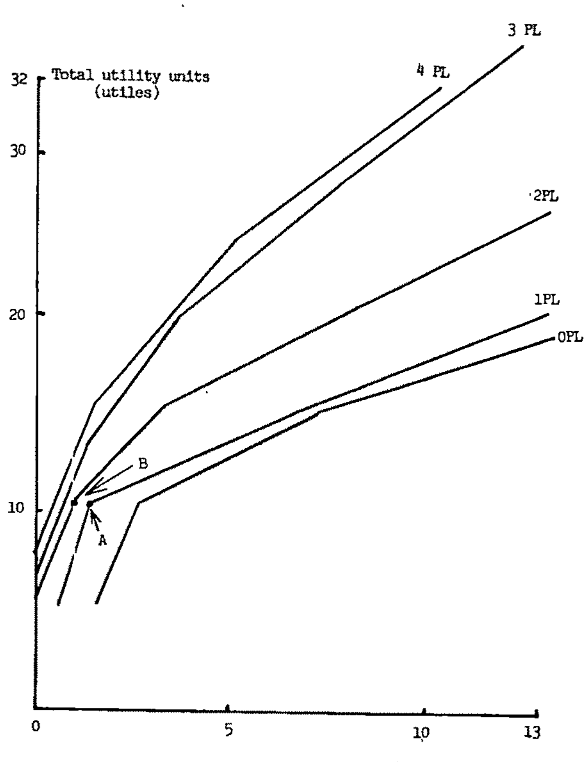


**Figure 2. Total utility curves for subject 2, by levels of days in the pool (*PL*)**

obtained for increasing quantities of recreation at this park and for increasing quantities of the recreation activity of outcome *b*. Finally the family of curves is transposed to give an indifference map.

## Empirical application of the model

The object of the empirical application was to derive benefit values, in dollars, for day use of a specific state park in Oregon. Thus the outcome in positions (i) and (iii) of the model were always quantities of this activity (*CSP*). In game 1 (Table 3) the quantity in position (i) was specified as 0 days as a convenient base point. The activity in position (ii), as outcome *b* in Table 2, was day use in the best alternative activity to recreation at the state park. This alternative was defined by the subject himself. In the example in Table 3, the best alternative was swimming at the city pool (*PL*). In game 1, the quantity was specified as one day. The third activity, as outcome *d* in position (iv) in Table 2, was now specified as a day visit to a unique natural resource, namely Crater Lake (*CL*). For convenience the quantity of this activity was specified as 0 days. A fourth activity, defined as staying at home, is also involved by implication. A time period of six weekends, or 12 weekend days, was specified. Experience in the pilot surveys indicated that subjects could offer consistent responses for choices over this period of time. The subjects were all of those from the field survey who lived in Corvallis, Oregon, and who were willing to co-operate.[10]

The subjects were presented with a series of games. Each game was written out in tabular form as in Table 3. They were asked, do you prefer prospect I or prospect II? The quantity *n* in item (iii) was varied until the subject was indifferent between the two prospects. Given this indifference, the expected utility from prospect I is equal to the expected utility from prospect II. Then, if *n* is 0.5 as in Table 3, and including the probabilities of 0.5,

$$(9)\quad 0.5\,U(0 \text{ days } CSP) + 0.5\,U(1 \text{ day } PL) = 0.5\,U(0.5 \text{ days } CSP) + 0.5\,U(0 \text{ days } CL).$$

Multiplying through by 2.0,

$$(10)\quad U(0 \text{ days } CSP) + U(1 \text{ day } PL) = U(0.5 \text{ days } CSP) + U(0 \text{ days } CL).$$

[10] Such a sample may bias the actual numerical results. But it does not affect the presentation of the utility approach that is the present objective. In practice the validation test, reported subsequently in this paper, lent some support to the actual numerical results.

Transposing,

$$(11) \quad U(1 \text{ day } PL) - U(0 \text{ days } CL) = U(0.5 \text{ days } CSP) - U(0 \text{ days } CSP).$$

A second game was then played. The indifference value of 0.5 days from (iii) in game one (Table 3) becomes the value of (i) in game two (Table 4). The new indifference value of (iii) was found as before. Let it be 1.25 days. By the logic of equations (9), (10), and (11), equation (12) was obtained.

$$(12) \quad U(1 \text{ day } PL) - U(0 \text{ days } CL) = U(1.25 \text{ days } CSP) - U(0.5 \text{ days } CSP).$$

As noted above, the left-hand side of equations (11) and (12) acts as a constant utility interval. The interval was scaled arbitrarily to 5 utiles. An arbitrary base for the scale was also chosen. Let $U(0\ CSP) = 0$. Then three points were known on a total utility curve, namely $U(0\ CSP) = 0$, $U(0.5\ CSP) = 5$, and $U(1.25\ CSP) = 10$. Further games were played, always transferring the indifference value of position (iii) in game $m$-1, to position (i) in game $m$. By indifference, the new value of (iii) was found. This procedure was continued until the quantity of *CSP* reached 12 days. The process provided a single total utility curve for the number of days taken at the state park (Fig. 2). The curve had a base of one day at the pool (1 *PL*) and zero days at Crater Lake (0 *CL*).

Next, total utility curves were calculated for different base levels of the alternative recreation activity. For subject two with an alternative activity of days in the pool, the levels were zero, two, three and four days. Each of the curves also incorporated zero days at Crater Lake in the base.[11] The calculation of a new total utility curve began by identifying the combination of days at the park (*CSP*) and at the pool (*PL*) at a specific point on an existing curve. For example, at a level of 10 utiles on the original total utility curve (point A in Fig. 2), the combination was 1.25 *CSP* and 1 *PL*. This combination was entered as prospect I in the Ramsey model with 1.25 *CSP* in position (i) and 1 *PL* in position (ii). Prospect II was a combination of 2 *PL* in position (iv), where the new total utility curve had a base of two days in the pool, and $n$ *CSP* in position (iii). Then in the usual way the indifference value of $n$ was found. In this example the value was 1.0 *CSP*. Therefore one point on the new total utility curve, of base 2 *PL*, was 1.0 *CSP* at a utility level of 10 utiles. This is point B in Figure 2. In practice, this game moved "horizontally across" the total utility map of Figure 2. By repeating such games at different utility levels, a second total utility curve was obtained. In similar fashion the entire family of total utility curves was obtained. The indifference map (Fig. 3) was obtained simply by transposing the total utility curves.

[11] In a further development for valuing option demand [9], the number of days at Crater Lake was varied from 0, through 1 to 2.

## Utility functions and benefit values

Selected utility functions for the five subjects are presented in Table 5. The high values for the coefficients of determination suggest that the polynomial is indeed a suitable function for the data. Only subject four showed significance on all five variables. An indifference map, fitted with a utility function, is shown in Figure 3.

Demand curves were derived from the indifference maps in the conventional manner. Data were obtained from each subject on product prices, or marginal costs of consuming the recreation activities, and on the available recreation budget. Points of tangency between price lines and indifference curves were calculated mathematically to give the quantities of the specific park activity (*CSP*, or $X_2$ in the utility functions) consumed at given prices. These were the data for the demand curve. Dollar values for the total benefit from days at the park were determined from the area under the curve. The values were adjusted for income and substitution effects to ensure that they represented values of successive days at the park against a fixed level of the alternative recreation activity ($X_1$

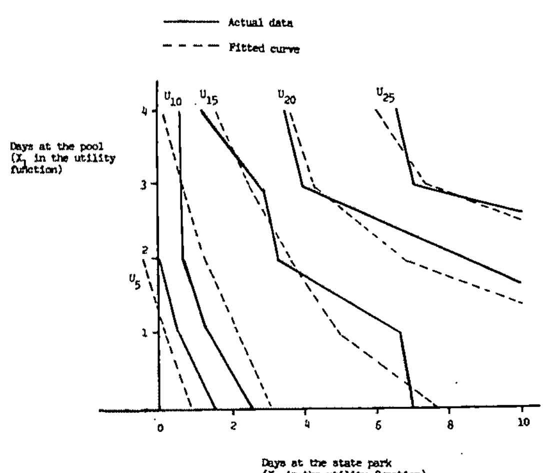


**Figure 3. The indifference map for subject 2[a]**

[a] The function for the fitted curve is given in Table 5.

Table 5. Utility function for five subjects

| Subject | | Utility Function[a] | | | | | Coefficient of Determination ($R^2$) |
|---|---|---|---|---|---|---|---|
| 1 | $U = 9.1$ | | | $+0.4X_1^2$ | | $+0.8X_1X_2$ | 71.6% |
| 2 | $U = 3.2$ | $+1.7X_1$ | $+2.3X_2$ | | $-0.1X_2^2$ | $+0.2X_1X_2$ | 96.0% |
| 3 | $U = 3.7$ | | | $+0.2X_1^2$ | | $+1.1X_1X_2$ | 84.9% |
| 4 | $U = -1.5$ | $+5.8X_1$ | $+2.1X_2$ | $-0.6X_1^2$ | $-0.1X_2^2$ | $-0.2X_1X_2$ | 92.2% |
| 5 | $U = 4.0$ | $+2.2X_1$ | $+3.2X_2$ | | | $+1.7X_1X_2$ | 92.0% |

[a] The insignificant terms have been dropped.
$X_1$ = the best alternative to the park. For subjects 1 and 2, this was the city swimming pool. For 3 and 4 it was the beach, and for 5 it was another park.
$X_2$ = days at the state park.

in the utility functions). Final dollar values are shown in Table 5. Consumer's surplus values are derived by deducting the marginal costs of a day at the park.

### Validation of the benefit values

Benefit values were validated by carefully specifying the parameters on which their absolute size depends and by testing for their predictive ability. Absolute size of the values depends on the prices and recreation budgets that were selected by the subject. The benefit values were sensitive to the size of the budget. Particular care was taken in determining this parameter. A 25 percent increase in the budget caused increases in benefit values of between 6 and 37 percent.

The relative size and empirical relevance of the benefit values was validated by testing for their predictive ability. The dependent variable was quantity of use of the park for each of the five families over the last 12 months. The only independent variable was the benefit value of the first day at the park for each family (from Table 6). In the regression model, the benefit values were significant at the 1 percent level and accounted for 94.3 percent of the variation in the dependent variable. This validation test was accepted as successful.

Table 6. Total benefit values for successive days at the state park per family group

| | Value of the Total Benefits in Dollars[a] | | | |
|---|---|---|---|---|
| Subject | Day 1 | Day 2 | Day 3 | Total |
| 1 | 1.8 | 0.6 | 0.5 | 2.9 |
| 2 | 3.6 | 1.0 | 0.6 | 5.2 |
| 3 | 6.0 | 2.7 | 1.3 | 10.0 |
| 4 | 4.7 | 2.7 | 1.0 | 8.4 |
| 5 | 6.7 | 2.5 | 1.5 | 10.7 |

[a] The net benefit or consumer's surplus requires deduction of the cost of one day of family use (approximately $1.4).

## Discussion

### Comparison of the two methods

The utility approach to benefit valuation required intensive face-to-face interviews. The experience with this approach indicated that expenditure of time and money resources on it and on the travel cost method would be similar for a given level of accuracy. If the costs of the two methods are similar, what are their relative merits?

The indifference mapping or utility approach offers several conceptual advantages. First, the consumer's surplus is identical with the traditional surplus concept and is derived directly from each individual.[12] In contrast, the travel cost procedure provides only an indirect measure of aggregate surplus. Thus the consumers surplus values from the utility approach for recreation can be compared with surplus values for other enterprises such as timber production or agriculture. The travel cost values are not identical with a specific consumer's surplus concept. Therefore the travel cost surplus values for recreation cannot be compared with values for other enterprises. They can only be compared with other recreation values also derived by the travel cost method. Second, the indifference approach treats time and money budgets separately and in accepted economic manner. The

[12] It is the Hicksian compensating variation of consumer's surplus.

travel cost procedure cannot, as conventionally used, separate these budgets out.

Data from the demand functions (Table 1) provide empirical support for the utility approach. The variable for intensity of preference ($X_9$) is a surrogate for the statistical form of the utility function relating preferences for an activity in various environments. This variable and a related variable ($X_{10}$) were consistently significant and the elasticities were, in all but one case, higher than the elasticity for distance. Use ($Q_r$) was therefore more responsive to preference (as measured) than to distance. These results also suggested that both utility and travel distance must be considered in a model of benefit evaluation. Further, differences in the direction and magnitude of the elasticities of the regression coefficients suggested that utility and cost should be considered separately. The utility approach meets these requirements. The travel cost method, as conventionally used, does not. Finally, in the validation test for the five subjects, the benefit values from the utility approach explained 94 percent of the variation in use. The travel cost function ($Q_4$ in Table 1) with four terms explained only 45 percent.

### Comparison of dollar values from the two methods

The travel cost procedure and the utility approach provided two estimates of consumer's surplus values of a specific recreation activity. A comparison of the values is not strictly valid because of the small size of the sample in the utility approach, the remaining assumptions of the travel cost method, and possible distortions due to the logarithmic transformation of distance in the present use of the travel cost procedure. However, the values are presented here since it is often argued that the travel cost method consistently underestimates the true values.

Values from the utility approach are listed in Table 6 as the total benefits per family. These data were used to derive an aggregate demand curve from which a consumer's surplus value of 76 cents per man-day was derived.[13] As noted above, the travel cost method gave a consumer's surplus value of 36 cents per man-day at the same site. In this limited comparison the travel cost method did indeed underestimate the values relative to the utility approach.[14]

### The aggregation debate again

The utility approach could provide a means to test further the various issues in the debate. In this approach the effect of income is incorporated directly through the price line. Thus the effect of actual and standardized incomes on consumption could readily be compared.

### Extensions of the utility approach

In the analysis of the survey data [9], the utility approach was extended to the valuation of option demand. Option demand involves uncertainty in future demand by the consumer and in the future supply of facilities. In contrast, the application to the state park reported in the present paper involved certainty in both demand and supply. The extension to option demand was empirically successful. In this extension the Ramsey model was tested against the von Neumann-Morgenstern model of utility estimation. The results were comparable.

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13 The aggregate demand curve for five families was derived as follows. At a price of \$6.5, the data in Table 6 indicate that only one unit is taken by family five. Thus one point in the curve is (\$6.5, 1 day). At \$6.0 families three and five will consume one unit each. Another point is therefore (\$6.0, 2 days). At the other end of the curve, at a price of \$1.4, nine days are taken. There are nine values in Table 6 over \$1.4 which is the approximate marginal cost of a family day for families from Corvallis (40 miles from the park). Therefore another point on the curve is (\$1.4, 9 days). The total area under this curve, above \$1.4 and thus up to a quantity of nine days, is \$19.1. This is the consumer's surplus that accrues to a total of nine visits from these five families. With 2.8 persons per family, and the assumption that all 2.8 members per family go each time, \$19.1 represents the surplus for 25.2 man-days. This is 76 cents per man-day.

14 This comparison makes a particular assumption. In the travel cost method the surplus was measured up to the mean quantity of use (19.5 hours). At this quantity the regression gave a mean one way distance of travel of 35 miles. It is implied therefore that the marginal user came from 35 miles distance (Footnote 9). In fact there were five out of 18 who came from further away. If the quantity of use had been increased beyond this mean, the actual consumer's surplus values per man-day would have decreased below the estimate of 36 cents due to the downward, logarithmic slope of the demand curve. The values from the utility approach also refer to a mean, but expected, quantity of use per person. With nine days for each of five families (Footnote 13), and if each family member goes on each 12 hour visit, the mean-use per person is 1.8 visits (9/5) or 22 hours. But this mean quantity was derived by noting the quantity at which the demand schedule intersected the price of \$1.4. Thus the particular assumption is that the subjects view costs of \$1.4 in the same way as a distance of 35 miles.

The utility approach has considered the valuation of the benefits gained in a specific recreation activity at a given state park in Oregon. The activity provided both recreational and aesthetic benefits. With a slightly different specification of the activities in the Ramsey model, the approach could be used for purely aesthetic or purely recreational experiences.

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# Factor Substitution in Colombian Agriculture*

Wayne Thirsk

**A declining labor share in agriculture is consistent with an elasticity of substitution between labor and other factors greater than unity. Using cross-section data drawn from a small sample of Colombian crop farms, this study develops a three-factor model and estimates the Allen-Uzawa partial substitution elasticities between the factor-pairs land, labor, and farm machinery. Both Ordinary and Generalized Least Squares estimation procedures provide elasticity estimates that agree with each other and with the results of recent and related research: a substitution elasticity between labor and machinery (capital) of about one and a half is strongly indicated.**

*Key words:* **factor substitution; Colombia; income share.**

Econometric estimation of a particular economic parameter has often cast up a disturbingly wide range of results from which to choose for empirical application. The width of the available range is perplexing because the conclusions of theoretical analysis are usually sensitive to the size of important parameters. Uncertainty of this kind hinders the contribution of economic theory to public policy debate. Moreover, the development of theory itself is retarded as contending schools of thought are created on the basis of differing assumptions about specific parameters.

Nowhere is this problem more evident than in the estimation of the elasticity of factor substitution. Issues involving the nature and significance of structural unemployment, the seriousness of unique factor supply constraints on economic growth, and the explanation of changed factor shares of total income have all relied on an inability to achieve agreement about the ease of factor substitution. In the nonagricultural sector(s) within the past 10 years, a proliferation of attempts to measure the elasticity of factor substitution has brought matters seemingly no nearer to resolution. In a comprehensive assessment of these efforts, Nerlove concluded somewhat gloomily that "the major finding of this survey is the diversity of results: even slight variations in the period or concepts tend to produce drastically different estimates of the elasticity" [7, p. 58]. Nothing that this author is aware of has happened since 1967 to overturn that judgment.

In the agricultural sector, however, the news is more cheerful, and a consensus on the ease of factor substitution appears to be emerging. The weight of available evidence presented here suggests the elasticity of substitution between farm machinery (capital) and labor exceeds unity and is closer to one and a half. This paper describes the outcome of an attempt to estimate substitution elasticities by crop for Colombian agriculture using a rather narrow data base. The first three sections outline respectively the nature of the data used, the specification of a theoretical production and factor demand model, and the tailoring of this model to develop two alternative sets of estimating equations. The next section reports and compares the results of the two estimation techniques. A subsidiary ambition in this paper is to compare these results with those that have been estimated from data for other countries and which employ alternative methodologies. In a final section the results achieved for Colombia are shown to be substantially compatible with previous research in the United States, United Kingdom, India, and Brazil.

## Data Source for the Colombian Case

The information required to estimate factor substitution elasticities was extracted from detailed individual farm records collected by the Colombian Land Reform Agency INCORA.[1] These records or *patrones* of per hectare inputs and outputs are used to evaluate the production performance of different farm units and different crops in the various land reform districts.

In addition to rice, cotton, and corn, results were obtained for wheat and barley and an aggregate crop combination labeled SSS, representing pooled observations on sesame, soybeans, and sorghum. Wheat and barley were also combined because of the similarity in their production

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[1] INCORA is the Instituto Colombiano para la Reforma Agraria.

process and the relatively small numbers of observations for each separate crop.

The data consisted of a cross-section sample drawn from different geographic areas of the country in 1968. Regional variation in factor and product prices and individual farm differences in risk attitudes and immobile factors such as soil type and management were relied upon to identify production surfaces for each crop.

Each *patron* provided precise information on the quantity of single crop output produced per hectare in the season and the price received for this output. Information on intermediate input use permitted the construction of value-added series per hectare. Amounts of the various inputs per hectare along with their prices were also available. From this information it was possible to derive measures of the share of each factor in total factor cost. Labor input was measured in man-days and the price of labor was the wage rate paid. Land rents paid formed the variable for the price of land.

The only major data concern was the specification of the capital variable. The price of capital was simply the rental paid for the use of tractors, combines, and spray planes. Because of limited degrees of freedom, it was necessary to develop some method of aggregation for the different components of farm machinery used. Ideally all three machinery rental prices should have been used independently to explain deflated capital expenditures per hectare.[2] Instead, two different procedures were followed. One method involved deflating capital expenditures by the rental price of tractors to convert the capital spending aggregate to equivalent tractor-hours and then using the same tractor rental price as the price of capital. This procedure was less than satisfactory because it ignored variation in the other machinery rental prices but was used, nevertheless, because most of the mechanized observations employed only tractors. With the second alternative, capital expenditures were deflated by an index of all the rental rates to obtain a measure of the real quantity of farm machinery used. The same weighted average of the machinery rental prices was taken as the price of capital with the weights determined by the share of each type of machinery in capital spending. This approach neglects substitution within the capital aggregate, such as the choice between the use of planes or tractors in applying insecticides.[3]

The other shortcomings of the data may also be mentioned. Since the data are restricted to farm units normally occupying less than 20 hectares, there is no guarantee the results would describe factor adjustments on much larger sized farms in Colombia, or elsewhere for that matter. Also, since the maximum (minimum) number of observations for any crop was 19 (11), the entire effort at estimating substitution parameters for various crops was hampered by the small number of observations available for each crop.

## Specifications of the Variables and Parameters

Given the existence of cross-section data, the development of a long-run factor substitution model seemed appropriate for estimating purposes. A three-factor production model was taken as the most promising approach for examining ease of substitution among different pairs of the factors: land, labor, and farm machinery. An alternative procedure of analyzing a two-factor relationship involving only labor and farm machinery appeared unnecessarily restrictive since it would require assuming that land was either strictly complementary to the use of the other two factors or was equally substitutable for either. If either of these assumptions were inaccurate, an attempt to explain the farm-machinery/labor ratio by relative capital-labor prices would be unsuccessful whenever there was significant variation in the price of land relative to the prices of the other two inputs. However, it is necessary to assume that all farms either operate on the same production function or, if not, that differences in efficiency are factor neutral and that each observation represents an equilibrium input position. Poor fits must occur to the extent these assumptions are unmet in the data.

Variables and parameters employed in the regression analysis are listed below. Input levels for labor and machinery refer to the entire span

[2] Since capital is demanded for its physical services, it is a measure of real capital that should enter the production function.

[3] This may not be a serious shortcoming, however, as comparisons with the same regression equation indicated that direct parameter estimates were not highly sensitive to the choice of one or the other specification. There seemed to be two reasons for this insensitivity. Few farms employed machinery other than tractors, and a relatively high tractor rental price was usually associated with relatively higher rental prices for other types of machinery. Thus it was hardly ever the case that a high tractor rental was offset by a low combine rental as an influence on total capital spending; thus tractor rentals served as an adequate proxy for capital costs in those cases where machinery use comprised more than the use of tractors.

of agricultural operations from initial land preparation to harvest.

$A,L,K$ = the physical inputs of land, labor, and capital, respectively;

$PA, PL, PK$ = the prices of land, labor, and capital, respectively;

$j$ = share of input $j$ in total costs;

$\Delta j = A,L,K$;

$\theta, P$ = the marginal cost of production and the gross output price, respectively;

$X$ = value-added measure of output;

$C$ = regression constant; $ln$ = the logarithmic operator;

and

$\sigma_{ij}$ = the Allen partial elasticity of substitution between factor $i$ and factor $j$ $\sigma_{ij} = \sigma_{ji} \lesseqgtr 0$, are *a priori* restrictions on the values of the partial elasticities. The symmetry restriction $\sigma_{ij} = \sigma_{ji}$ was a maintained hypothesis in the estimating equations of the regression models below.[4]

## Specification of the Model and Estimating Equations

Suppose each farm operates along a constant returns to scale production function represented by $X = X(A,L,K)$. For any given output level the farm combines factors so as to minimize total costs. First-order conditions for this minimization require $X = X(A,L,K)$ and $X_i\theta = P_i$, $i = A,L,K$. Totally differentiating these equilibrium conditions gives the following:

$$\begin{bmatrix} O & X_1 & X_k & X_a \\ X_1 & X_{11} & X_{1k} & X_{1a} \\ X_k & X_{a1} & X_{kk} & X_{ka} \\ X_a & X_{k1} & X_{ak} & X_{aa} \end{bmatrix} \cdot \begin{bmatrix} \frac{d\theta}{\theta} \\ dL \\ dK \\ dA \end{bmatrix} = \begin{bmatrix} dX \\ \frac{dPL}{\theta} \\ \frac{dPK}{\theta} \\ \frac{dPA}{\theta} \end{bmatrix}$$

Let $F_o$ = the determinant of the above bordered Hessian matrix; $F_{ij}$ = co-factor of $X_{ij}$, $F_{oj}$ = co-factor of $X_j$, and note that $F_{oj}/F_o$ = input $j/X$ following Allen [1, p. 482]. The Allen-Uzawa partial substitution elasticity between labor and capital $\sigma_{lk}$ is defined as $X/LK \cdot F_{lk}/F_o$.

If factor prices are allowed in turn to vary, changes in the level of demand for any factor can be expressed from the above equations as the weighted sum of factor price changes plus the proportional change in the level of output produced. To illustrate in the case of labor, $dL/L = \sum_j \Delta j \sigma_{lj} \; dP_j/P_j + dX/X;\; j = A,K,L.$ Also, changes in marginal costs can be represented as the weighted sum of factor price changes with the weights being the appropriate factor shares: $d\theta/\theta = \sum_j \Delta j \; dP_j/P_j;\; j = A,K,L.$ If the expressions for changes in factor demand and marginal costs are viewed as a system of differential equations and if second-order effects are ignored, each expression can be integrated to give a first-order approximation to the structural factor demand and average cost equations used in the regression models.[5]

$$(1)\quad \ln A = C_1 + \Delta K\sigma_{ak} \ln PK + \Delta L\sigma_{al} \ln PL + \Delta A\sigma_{aa} \ln PA + \ln X$$

$$(2)\quad \ln L = C_2 + \Delta K\sigma_{kl} \ln PK + \Delta L\sigma_{ll} \ln PL + \Delta A\sigma_{la} \ln PA + \ln X$$

$$(3)\quad \ln K = C_3 + \Delta K\sigma_{kk} \ln PK + \Delta L\sigma_{lk} \ln PL + \Delta A\sigma_{ak} \ln PA + \ln X$$

$$(4)\quad \ln\theta = C_4 + \Delta K \ln PK + \Delta L \ln PL + \Delta A \ln PA$$

The logarithm of each factor demand is a linear function of the logarithms of all factor prices and the level of output. Coefficients of the factor price terms are the products of factor shares and the partial substitution elasticities of the underlying production function. Equation (4) underlines the fact that marginal costs are independent of output levels in the long run. For any constant returns to scale production function, farm size is indeterminate. A variety of farm sizes and outputs can coexist at any moment in time, but

[4] The partial elasticities have a conventional interpretation. If $\sigma_{ij} > 1$, then a 1 percent increase in the factor price ratio $Pi/Pj$ will provoke a larger than 1 percent increase in the ratio of factor $j$ to factor $i$, and the share of factor $j$ in total costs or proceeds will rise. Also, if $\sigma_{ij}$ is less than zero, factors $i$ and $j$ are complements in that an increase in the relative price of one of them will cause reduced use of the other. Factors $i$ and $j$ are substitutes if $\sigma_{ij}$ is positive. Partial elasticities are defined as described in [1, pp. 503–508].

[5] The first order terms in the solution to the differential equations contain factor shares fixed at the initial level; the second order, and ignored, terms involve changes in the factor shares in combination with the factor price changes.

if all farms were to confront the same factor and product prices, the ratios of one input to another or of output to any input would be uniform across all farms. If the industry is in long run equilibrium, adjustments in the scale of farms occur until output price equals marginal and average costs of production. Thus $P$ is set equal to $\theta$ in the subsequent specifications of long run equilibrium behavior. Actually, since only gross output price is observed and intermediate inputs are excluded from consideration, setting $P = \theta$ invokes the assumption that prices and marginal costs are proportional rather than equal for all observations.

The main advantage to formulating the model in terms of derived demand functions is one of flexibility. Known production function forms incorporating more than two factors impose the rigidity that either all partial elasticities are equal (the Cobb-Douglas and constant elasticity cases) or that their ratios or differences are equal [5]. Moreover, the set of neoclassical factor demand equations contain the partial elasticities as directly estimable parameters. Estimating the production function, on the other hand, would likely require estimating a host of other production parameters in order to derive the same partial elasticity. It is simpler to make inferences about the characteristics of the unobserved production function on the basis of observable factor demand relationships.

Although variable in theory, the partial elasticities are assumed to be constant over the observed range of the data for estimation purposes. An additional constraint on the values of the partial elasticities is the homogeneity condition $\sum_j^3 \Delta j \sigma_{ij} = 0$, which means that only three of the partial elasticities can be determined independently. Given estimates of $\sigma_{ka}$, $\sigma_{kl}$, and $\sigma_{la}$ and information on factor shares, all of the own-substitution parameters, $\sigma_{aa}$, $\sigma_{kk}$, and $\sigma_{ll}$, follow from the homogeneity condition.

The relationships in the basic model were used to generate two different econometric specifications of the choice of factor proportions in mechanized agriculture. These different approaches can be considered as a family of regression models which differ according to the prior assumptions each imposes on the data. In the first approach direct estimates of each substitution parameter $\sigma_{ij}$ were obtained by substitution of equation (4) into equations (1), (2), and (3) and using the homogeneity condition to yield the three sets of estimating equations below.

$$
\begin{aligned}
(5.1) \quad \ln X/L &= C + \sigma_{kl} \ln \frac{PL}{P} + \Delta A(\sigma_{al} - \sigma_{kl}) \ln \frac{PL}{PA} \\
\ln X/L &= C + \sigma_{kl} \ln \frac{PA}{P} + \Delta L(\sigma_{kl} - \sigma_{ll}) \ln \frac{PL}{PA} \\
(5.2) \quad \ln X/A &= C + \sigma_{al} \ln \frac{PA}{P} + \Delta K(\sigma_{al} - \sigma_{ka}) \ln \frac{PK}{PA} \\
\ln X/A &= C + \sigma_{al} \ln \frac{PK}{P} + \Delta A(\sigma_{aa} - \sigma_{al}) \ln \frac{PK}{PA} \\
(5.3) \quad \ln X/K &= C + \sigma_{ka} \ln \frac{PK}{P} + \Delta L(\sigma_{ka} - \sigma_{kl}) \ln \frac{PL}{PK} \\
\ln X/K &= C + \sigma_{ka} \ln \frac{PL}{P} + \Delta K(\sigma_{kk} - \sigma_{ka}) \ln \frac{PL}{PK}
\end{aligned}
$$

Using set (5.1) as an example, these equations can be interpreted in the following manner. Holding the factor price ratio $PL/PA$ constant in the regression rules out substitution between the factor pair of land and labor. Thus an increase in the real price of labor $PL/P$ implies an increase in the factor price ratio $PL/PK$, and the subsequent substitution of capital for labor is picked up in the positive variation of average labor productivity $X/L$.

As long as factor shares $\Delta j$ are considered to be parameters in the regression equation, the second equation in set (5.1) must yield an identical estimate of the substitution parameter $\sigma_{kl}$, since it involves a linear combination of the same independent variables as in the first equation.[6] However, if factor shares are allowed to vary, and

[6] This relationship is easy to discern. If $B_j$ represents a regression coefficient, the first equation takes the regression form of $\ln X/L = C + B_1 (\ln PL - \ln P) + B_2 (\ln PL - \ln PA)$. Adding and subtracting $B_1 \ln PA$ to this equation results in $\ln X/L = C + B_1 (\ln PA - \ln P) + (B_1 + B_2)(\ln PL - \ln PA)$ so that the regression form of the second equation $\ln X/L = C + B_3 \ln PA/P + B_4 \ln PL/PA$ implies the equalities $B_1 = B_3$ and $(B_1 + B_2) = B_4$ must hold between the two equations.

the independent variables become share-weighted factor price ratios, the equalities above no longer hold, and there is no guarantee that the alternative forms of any equation set will yield the same estimate of $\sigma_{ij}$. Specifications which regarded the factor shares as variable were thought to be more appropriate since only in the special Cobb-Douglas case would one expect constant factor shares to accompany varying factor prices. Also, by permitting factor shares to vary with each observation, it was possible to identify more than one substitution parameter in each equation. In set (5.1), for example, $\sigma_{al}$ can be recovered from the regression coefficient for the variable $\Delta A \ln \frac{PL}{PA}$ given the point estimate of $\sigma_{kl}$ from the regression coefficient for $\frac{PL}{P}$.

When a stochastic disturbance term is added to the different equation sets (5.1), (5.2), and (5.3), the equations that have been described can be estimated by Ordinary Least Squares since each independent variable can be considered as exogeneous at the firm level. The usual assumptions about the disturbance term are made—that is, it is identically and independently distributed log-normal and has an expectation of zero.

A second approach was developed as a safeguard against some of the difficulties associated with the first. A potential problem with the first regression set (5) is that it may be subject to measurement errors in value-added. Another shortcoming is the difficulty of imposing desirable cross-equation restrictions on the three sets of estimating equations. The second coefficient in any set may generate a value for $\sigma_{ij}$ which differs from the value for $\sigma_{ij}$ generated by the first coefficient in some other set. Moreover, two estimates of $\sigma_{ii}$ are possible—one from the values for $\sigma_{ij}$ and the other from the regression itself—because although homogeneity has been imposed, the estimates of $\sigma_{ij}$ may not imply that it holds. Using equations (1) to (3) and imposing homogeneity to eliminate $\sigma_{ii}$ terms, the amounts of machinery and labor demanded per unit of land can be expressed in a way that permits the direct estimation of all $\sigma_{ij}$ values. The two equations are as follows:

$$(6.1)\quad \ln\frac{K}{A} = C_0 + \sigma_{ka}\,\{(1-\Delta L)\ln\frac{PA}{PK}\} + \sigma_{kl}\,\{\Delta L \ln\frac{PL}{PK}\} + \sigma_{la}\,\{\Delta L \ln\frac{PA}{PL}\}$$

$$(6.2)\quad \ln\frac{L}{A} = C_1 + \sigma_{ka}\,\{\Delta K \ln\frac{PA}{PK}\} + \sigma_{kl}\,\{-\Delta K \ln\frac{PL}{PK}\} + \sigma_{la}\,\{(1-\Delta K)\ln\frac{PA}{PL}\}.$$

Because both equations provide estimates of the same parameters, it was desirable to estimate both equations simultaneously under the imposed constraint that $\sigma_{ij}$ have the same value in each equation. An adaptation of Generalized Least Squares (GLS) developed by Zellner [11] was the estimating technique employed to satisfy these conditions. This procedure is asymptotically more efficient than single-equation least squares because it takes account of zero restrictions on coefficients occurring in other equations.

In order to conserve on scarce degrees of freedom, the use of intermediate inputs was purposely overlooked. This omission could be a potential source of specification error biasing in either direction the measured from the true partial elasticity of substitution. This bias could be prevented from appearing only if certain conditions were met. If, for example, any intermediate input, denoted by the subscript $i$, was added to the factor demand equations developed above, the labor to land ratio could be expressed as

$$\ln L/A = C + \Delta K(\sigma_{lk} - \sigma_{ka}) \ln PK/PA + \Delta L(\sigma_{ll} - \sigma_{al}) \ln PL/PA + \Delta I(\sigma_{li} - \sigma_{ai}) \ln PI/PA.$$

In a regression equation which omitted the last term, the expected value of the regression coefficient for the variable $\Delta K \ln PK/PK$ would be $(\sigma_{lk} - \sigma_{ka}) + (\sigma_{li} - \sigma_{ai}) \quad B_i$ where $(\sigma_{lk} - \sigma_{ka})$ is the regression coefficient obtained by including the intermediate input in the regression; $B_i$ is the regression coefficient for the variable $\Delta K \ln PK/PA$ in the regression of $\Delta I \ln PI/PA$ on $\Delta K \ln PK/PA$ and $\Delta L \ln PL/PA$. Therefore, no bias would appear if any one of three conditions could be established. If $\sigma_{li} = \sigma_{ai}$ so that intermediate inputs were either strictly complementary with or equally substitutable for other factors, or if the covariance of $\Delta I \ln PI/PA$ and $\Delta K \ln PK/PA$ were zero, the ommission of intermediate inputs would not bias the size of other parameter estimates.[7]

[7] It is difficult to guess at the likely direction of any bias. If the covariance term is positive, and if intermediate inputs are a better substitute for land than for labor, the partial elasticities estimated from the

Table 1. Point estimates of substitution elasticities

| | Regression Specification[a] | Parameter | Rice | Cotton | Corn | SSS | Wheat and Barley |
|---|---|---|---|---|---|---|---|
| (5.1) | (not share weighted)[b] | $\sigma_{kl}$ | 2.22 | .90 | 1.48 | .98 | —.087 |
| (5.1) | (share weighted)[b] | | 1.59 | .96 | .90 | .94 | .03 |
| (6) | (GLS) I[c] | | 1.43 | 1.88 | 1.44 | 1.30 | 1.07 |
| (6) | (GLS) II[c] | | 1.44 | 1.87 | 1.44 | 1.30 | 1.08 |
| (5.2) | (not share weighted) | $\sigma_{la}$ | 1.18 | .35 | .28 | .12 | —.83 |
| (5.2) | (share weighted) I | | .36 | .54 | .55 | .42 | .02 |
| (5.2) | (share weighted) II | | .67 | .63 | .55 | .20 | .08 |
| (5.1) | (share weighted) | | .67 | .61 | .30 | .89 | —.55 |
| (6) | (GLS) I | | .79 | —.02 | .78 | .55 | .44 |
| (6) | (GLS) II | | .57 | .51 | .80 | .44 | .87 |
| (5.3) | (not share weighted) | $\sigma_{ka}$ | .25 | .04 | .63 | —.04 | —4.25 |
| (5.3) | (share weighted) I | | —1.09 | —1.73 | —.85 | .26 | —1.29 |
| (5.3) | (share weighted) II | | —.85 | —1.7[illegible] | —.80 | .62 | —1.19 |
| (6) | (GLS) I | | —.34 | —.1[illegible] | —.65 | .13 | .04 |
| (6) | (GLS) II | | —.29 | —.50 | —.69 | .20 | —.051 |

[a] Numbers in parentheses refer to the specific equations within each specification as designated in the text of this paper. Complete regression results for each specification are shown in Appendix Tables 1 through 4.

[b] "Not share weighted" and "share weighted" refer to whether or not the factor price ratios were multiplied by factor cost shares prior to estimation.

[c] I and II refer to the different capital price and quantity concepts discussed in the data section.

## Regression Results

Table 1 presents the point estimates of the partial elasticities derived from regressions on the INCORA data. Complete regression results appear in Appendix Tables 1 to 4. It is obvious that all of the crops analyzed did not meet with equal success. Rice and cotton were consistently the best performers in all cases with the trio of sesame, soybeans, and sorghum not far behind. Corn had a mixed record, performing well in some cases and badly in others. Wheat and barley were extremely erratic and not much confidence could be placed in any of the results for these crops.

The partial elasticity of substitution between farm machinery and labor was invariably higher than the elasticities between other factor pairs in model A. Point estimates of $\sigma_{kl}$ for various crops gave significant values of 1.59 for rice and about unity for cotton, corn, and the combined sesame, soya, and sorghum crops. Point estimates for the other elasticities were well under one with the elasticity between land and labor usually exceeding that between land and farm machinery. Most of the regression estimates produced a fairly strong and significant negative elasticity for the machinery-land substitution parameter, suggesting a complementary relationship existed for this factor pair, perhaps as a result of machinery indivisibilities. Thus a higher machinery-labor ratio tends to be accompanied by a higher ratio of land to labor. When point estimates of the differences between various partial elasticities were examined in model A, the above ranking of the elasticities in terms of relative size continued to hold up. Ease of substitution appeared to be highest between farm machinery and labor, next highest between land and labor, and least between land and farm machinery.

Generalized Least Squares estimates from model B, which imposed the constraint of equal substitution elasticities between the two equations, met with almost unqualified statistical success. These estimates are shown in Appendix Table 4. Except for cotton and wheat and barley, all the estimated substitution parameters were significant to at least the 10 percent level. Of the 30 estimated substitution elasticities, 26 were significantly different from zero, and the gain in efficiency over single-equation estimates was to be expected.[8] For all crops the elasticity of substitution between farm machinery and labor exceeded one with a range of 1.07 to 1.88 and an unweighted average value of 1.43. Except for cotton, the substitution elasticity between land and labor was less than one and greater than zero with a range of .44 to .8. Between farm machinery and land, the substitution elasticity was

per hectare regression forms may be downwardly biased from their "true" values.

[8] It should be pointed out that there is an intractable "identification" problem here. A value for $\sigma_{ij}$ insignificant from zero may indicate fixed proportions but is also consistent with either a bad specification or bad data.

significantly negative, indicating complementarity, for rice, cotton, and corn; barely positive for the SSS aggregate; and insignificant from zero in the case of wheat and barley. These results conform quite closely to those for model A, and relative stability of the estimates between these two different models lends support for their reasonableness.

In view of the small number of observations employed in these regressions, it would be reckless to generalize these findings. Because of small degrees of freedom, not a great deal of confidence can be placed in the point estimates. They should be regarded as highly tentative pending additional evidence and confirmation. A noticeable deficiency of these estimates is that they assume cost minimization actually occurs so that the measured partial elasticities of substitution describe only the technological properties of various crops. Accordingly, it is of some interest to examine the outcome of related research in other countries.

## Other Research on the Ease of Capital-Labor Substitution in Agriculture

Outside of Colombia, empirical research into the ease of agricultural factor substitution has been largely confined to the United States and Western Europe, including Britain. For the United States, Lianos [6] has recently sought to explain the decline in agricultural labor's relative income share through the use of a neoclassical production framework. Lianos employed time-series data over the period 1949–68 for a comprehensive definition of the agricultural sector encompassing both crops and livestock.

After noting that labor's income share had fallen by about 50 percent between 1949 and 1968, Lianos relied on the specification of an aggregate, two-factor (capital and labor), CES production function to explain this decline. One of Lianos' equations fittted the data well and generated a value for the substitution elasticity of 1.52 while another, after it had been transformed and estimated by Autoregressive Least Squares, produced a similar value of 1.60. These results are quite consistent with earlier efforts to estimate the demand elasticities for labor and tractors in U. S. agriculture. Elasticities of labor demand, $\partial \ln L/\partial \ln PL$, had been previously estimated by Bauer [2] as $-1.43$ and by Wallace and Hoover [10] as $-1.48$. Griliches [4], on the other hand, had estimated the long-run price elasticity of demand for tractors, $\partial \ln T/\partial \ln PT$, at $-1.5$. By inference, then the elasticity of substitution between tractors and labor, $\partial \ln (T/L)/ \partial \ln (PL/PT)$, would also be close to one and a half, a value which would conform to Lianos' results if tractors were a reasonably stable proportion of his definition of total capital expenditure.

For Western Europe the issue of factor substitution in agriculture has been recently explored and summarized by Scott and Smyth [9]. They consider both cross-section data for 16 OECD countries and time-series information for Britain as a means of illustrating the variability of the farm machinery-labor ratio $T/L$ in response to price variation of these factors.

Utilizing a multi-factor CES production function, their regression equation is of the form $\ln T/L = C + \sigma \ln PT/PL$. Fitted cross-sectionally to Western Europe, this equation performed well and gave rise to a value for $\sigma$ of about 2. Smyth and Scott note that the data display a positive correlation between farm size and the price of labor. They surmise that this correlation reflects the immobility of farm labor on small farms so that market wages are an inadequate indicator of opportunity costs for this group of farmers. In these circumstances, the $T/L$ ratio on a small farm, or in countries with many small farms, would be smaller than the model would predict on the basis of the relative tractor-labor price. When average farm size becomes an additional variable in the regression model, the elasticity of substitution is reduced in size from 2 to 1.66–1.71. Moreover, permitting non-neutral technical progress to affect the tractor-labor ratio further reduces the value for $\sigma$ to 1.43. Similar results are also obtained from an examination of time-series data for the U. K.

In India, Evenson [3] employed quadratic functional forms to estimate production relationships contained in the data extracted from farm management surveys. As part of a two-stage procedure he calculates that the pair-wise substitution elasticity between tractors and labor is 1.44, a value in close agreement with the other studies.

Finally, drawing on census data for all Brazilian states in 1950 and 1960, Sanders [8] found that the elasticity of substitution between tractors and labor fluctuated between 1.35 and 1.6. Sanders utilized the same CES production function framework as Scott and Smyth except that he allowed more variables to influence the tractor-labor ratio than relative tractor-labor prices and farm size distribution. The intensity of farm operation, measured by per hectare ex-

penditures on bio-chemical inputs, and the mix of crops between permanent and annual crops also affected the degree of mechanization.

## Conclusions

Contrary to Nerlove's conclusion for the non-agricultural sectors, the main finding of this exercise and partial survey is the uniformity of results. Differences in data and estimating procedures produce essentially the same answer: the elasticity of capital-labor substitution in agriculture exceeds unity and is probably close to one and a half. This parameter size appears to be virtually independent of the choice of time-period, the use of inter-country versus intra-country data, or of time-series versus cross-section information. Choice of functional form also seems to matter little. Three factor variable elasticity functions gave comparable results to two factor and multiple factor CES formulations. It must be admitted, however, that these comparisons have not been carried out on a systematic basis. That is, the stability of $\sigma$ has been observed for different specifications on different data sources. Ideally, insensitivity to aggregation, specification, and time period should be tested on the same data source. Despite the absence of such a data source, it is hard to believe that the clustering of estimated values for the substitution elasticity about a common level is all happenstance. The chances are that this convergence accurately reflects the relatively wide range of alternative agricultural techniques available for adoption at any moment of time.

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## APPENDIX

**Table 1. Partial substitution elasticity between capital and labor with and without factor share weights[a]**

| (1) $\ln \frac{VA}{L}$ | $C$ | $\ln \frac{PL}{P}$ | $\Delta A \ln \frac{PL}{PA}$ | Number of Observations | $R^2$ | D.W.[b] |
|---|---|---|---|---|---|---|
| Rice | −1.48 | 2.22*[e] | −.89* | 13 | .47 | 1.75 |
| | (−1.19)[d] | (2.33) | (−1.87) | | | |
| Cotton | .979 | .90* | −.155 | 11 | .56 | 2.02 |
| | (2.45) | (2.95) | (−1.14) | | | |
| Corn | −.70 | 1.48* | −.54* | 19 | .27 | 1.84 |
| | (−.66) | (2.34) | (−1.82) | | | |
| SSS[c] | 1.12 | .98* | −.007 | 19 | .67 | 1.04 |
| | (3.73) | (5.27) | (−.04) | | | |
| Wheat and Barley | 3.75 | −.087 | .84 | 14 | .09 | 2.23 |
| | (2.58) | (−.103) | (1.03) | | | |

| (2) $\ln \frac{VA}{L}$ | $C$ | $\ln \frac{PL}{P}$ | $\Delta A \ln \frac{PL}{PA}$ | Number of Observations | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| Rice | .039 | 1.59** | −.915* | 13 | .49 | 2.6 |
| | (.041) | (1.62) | (−2.00) | | | |
| Cotton | 1.026 | .96* | −.37* | 11 | .71 | 2.31 |
| | (5.16) | (4.46) | (−2.49) | | | |
| Corn | .47 | .90** | −.601* | 19 | .40 | 1.46 |
| | (.65) | (1.68) | (−3.05) | | | |
| SSS | 1.086 | .94* | −.145 | 19 | .68 | 1.19 |
| | (6.04) | (5.23) | (−.80) | | | |
| Wheat and barley | 2.73 | .03 | .584 | 14 | .05 | 1.83 |
| | (2.96) | (.03) | (.69) | | | |

[a] The form for both sets is

$$\ln \frac{VA}{L} = C + \sigma_{kl} \ln \frac{PL}{P} + (\sigma_{al} - \sigma_{kl}) \; \Delta A \ln \frac{PL}{PA}.$$

In the first set, the share of land $\Delta A$ is assumed constant; in the second set it is entered as a variable. $C$ is a constant. For description of the price and quantity variables, see the discussion of data in the text.

[b] D.W. is the Durbin-Watson statistic.

[c] SSS refers to the aggregation of sesame, soybeans, and sorghum.

[d] $t$-values are entered in parentheses under each regression coefficient.

[e] A single asterisk (*) denotes significance at the 5 percent level, a double asterisk (**) at the 10 percent level.

Table 2. Partial substitution elasticity between land and labor with and without factor share weights[a]

| (1) $\ln \frac{VA}{A}$ | $C$ | $\ln \frac{PA}{P}$ | $\Delta K \ln \frac{PK}{PA}$ | Number of Observations | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| Rice | 1.38 | 1.18 | .72 | 13 | .18 | 1.95 |
| | (.51) | (.72) | (.51) | | | |
| Cotton | 3.6 | .35 | —.94** | 11 | .42 | 2.10 |
| | (4.5) | (.57) | (—1.51) | | | |
| Corn | 2.26 | .284*[b] | —.286** | 19 | .60 | 2.32 |
| | (5.56) | (1.79) | (—3.15) | | | |
| SSS | 2.82 | .12 | —.255** | 19 | .41 | 1.28 |
| | (15.9) | (1.31) | (—1.39) | | | |
| Wheat and Barley | 4.25 | —.83** | —1.097* | 14 | .26 | 2.02 |
| | (5.07) | (—1.66) | (—1.95) | | | |

| (2) $\ln \frac{VA}{A}$ | $C$ | $\ln \frac{PA}{P}$ | $\Delta K \ln \frac{PK}{PA}$ | Number of Observations | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| Rice | | | | | | |
| I[c] | 2.68 | .364 | .017 | 13 | .16 | 2.76 |
| | (2.48) | (.77) | (.035) | | | |
| II | 2.12 | .67* | .882** | 13 | .30 | 2.93 |
| | (2.87) | (2.06) | (1.40) | | | |
| Cotton | | | | | | |
| I | 2.48 | .64* | .83** | 11 | .79 | 1.97 |
| | (7.58) | (5.08) | (1.72) | | | |
| II | 2.49 | .63* | .676* | 11 | .80 | 1.98 |
| | (7.80) | (5.04) | (1.84) | | | |
| Corn | | | | | | |
| I | 2.02 | .55* | .61** | 17 | .53 | 2.22 |
| | (5.55) | (3.93) | (1.61) | | | |
| II | 2.00 | .55* | .51** | 17 | .50 | 2.21 |
| | (5.29) | (3.72) | (1.30) | | | |
| SSS | | | | | | |
| I | 2.67 | .42* | .87* | 19 | .56 | 1.23 |
| | (16.05) | (4.47) | (3.03) | | | |
| II | 2.88 | .20* | .006 | 19 | .31 | .72 |
| | (15.34) | (2.20) | (.015) | | | |
| Wheat and Barley | | | | | | |
| I | 3.58 | .02 | .71* | 13 | .30 | 1.92 |
| | (6.09) | (.10) | (2.01) | | | |
| II | 3.50 | .08 | .951* | 13 | .31 | 1.82 |
| | (6.00) | (.32) | (2.08) | | | |

[a] The format is the same as in Appendix Table 1. The regression form is:

$$\ln \frac{VA}{A} = C + \sigma_{al} \ln \frac{PA}{P} + (\sigma_{al} - \sigma_{ak}) \ \Delta K \ln \frac{PK}{PA}.$$

[b] A single asterisk (*) denotes significance at the 5 percent level, a double asterisk (**) at the 10 percent level.

[c] For set (2) two regressions were run, one using the tractor rental for $PK$ (I) and the other using a weighted rental price for all machinery (II) (see discussion in the text).

**Table 3. Partial substitution elasticity between capital and land with and without factor share weights[a]**

| (1)[b] $\ln \frac{VA}{K}$ | $C$ | $\ln \frac{PK}{P}$ | $\Delta L \ln \frac{PL}{PK}$ | Number of Observations | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| Rice | −1.81 | .25*[c] | −1.71* | 13 | .73 | 2.75 |
| | (−1.12) | (2.09) | (−3.28) | | | |
| Cotton | 2.40 | .04 | −.512 | 11 | .17 | 1.81 |
| | (1.08) | (.023) | (−.89) | | | |
| Corn | .001 | .63* | −2.77* | 19 | .82 | .83 |
| | (.004) | (1.76) | (−3.46) | | | |
| SSS | 2.18 | −.04 | −.48** | 19 | .13 | 1.24 |
| | (10.25) | (−.26) | (−1.43) | | | |
| Wheat and Barley | 10.54 | −4.25* | −4.57* | 13 | .59 | 1.57 |
| | (4.86) | (−2.97) | (−2.21) | | | |

| (2)[d] $\ln \frac{VA}{K}$ | $C$ | $\ln \frac{PL}{P}$ | $\Delta K \ln \frac{PL}{PK}$ | Number of Observations | $R^2$ | D.W. |
|---|---|---|---|---|---|---|
| Rice | | | | | | |
| I | 2.05 | −1.09** | −.641** | 13 | .48 | 2.41 |
| | (3.38) | (−1.74) | (1.57) | | | |
| II | 3.43 | −.85 | −.878** | 13 | .24 | 2.36 |
| | (4.56) | (−1.08) | (−1.73) | | | |
| Cotton | | | | | | |
| I | 4.52 | −1.73* | 3.98* | 11 | .75 | 3.26 |
| | (12.28) | (−4.65) | (4.37) | | | |
| II | 4.32 | −1.72* | 3.56** | 11 | .35 | 1.95 |
| | (5.2) | (−2.06) | (1.60) | | | |
| Corn | | | | | | |
| I | 3.62 | −.85* | .87 | 19 | .37 | 1.49 |
| | (8.89) | (−2.34) | (.97) | | | |
| II | 3.58 | −.80* | 1.12 | 19 | .41 | 1.80 |
| | (8.97) | (−2.21) | (1.24) | | | |
| SSS | | | | | | |
| I | .563 | .26** | .96* | 19 | .40 | 1.38 |
| | (4.58) | (1.43) | (2.91) | | | |
| II | 1.96 | .62* | .34 | 19 | .40 | 1.66 |
| | (12.12) | (2.57) | (.79) | | | |
| Wheat and Barley | | | | | | |
| I | 2.44 | −1.286* | 2.43* | 13 | .78 | 2.00 |
| | (5.92) | (−3.05) | (5.11) | | | |
| II | 3.85 | −1.19* | 1.03* | 13 | .51 | 1.85 |
| | (8.51) | (−2.59) | (1.99) | | | |

[a] The format is the same as in Appendix Table 2.

[b] The regression form of set (1) is

$$\ln \frac{VA}{K} = C + \sigma_{ka} \ln \frac{PK}{P} + (\sigma_{ka} - \sigma_{kl}) \ \Delta L \ln \frac{PL}{PK};$$

for set (2) it is:

$$\ln \frac{VA}{K} = C + \sigma_{ka} \ln \frac{PL}{P} + (\sigma_{kk} - \sigma_{ka}) \ \Delta K \ln \frac{PL}{PK}.$$

[c] A single asterisk (*) denotes significance at the 5 percent level, a double asterisk (**) at the 10 percent level.

[d] For set (2) two regressions were run, one using the tractor rental for $PK$ (I) and the other using a weighted rental price for all machinery (II) (see discussion in the text).

Table 4. Constrained simultaneous estimation of partial substitution elasticities[a]

| Crop | Parameters $\sigma_{kl}$ | $\sigma_{al}$ | $\sigma_{ka}$ |
|---|---|---|---|
| Rice | | | |
| I[b] | 1.43*[c] | .79* | —.34* |
| | (28.6)[d] | (4.16) | (—2.13) |
| II | 1.44* | .57* | —.29* |
| | (27.1) | (5.85) | (—2.11) |
| Cotton | | | |
| I | 1.88* | —.02 | —.13 |
| | (29.3) | (—.0013) | (—.60) |
| II | 1.87* | .54* | —.50* |
| | (29.2) | (2.29) | (—3.29) |
| Corn | | | |
| I | 1.44* | .786* | —.655* |
| | (30.6) | (2.55) | (—2.17) |
| II | 1.44* | .80* | —.687* |
| | (36.0) | (3.40) | (—3.37) |
| SSS | | | |
| I | 1.30* | .55* | .133** |
| | (11.8) | (5.34) | (1.33) |
| II | 1.30* | .44* | .20** |
| | (40.6) | (3.33) | (1.63) |
| Wheat and Barley | | | |
| I | 1.07* | .44* | .04 |
| | (12.74) | (3.60) | (.028) |
| II | 1.08* | .487* | —.051 |
| | (12.0) | (1.85) | (—.038) |

[a] The estimation method is constrained Generalized Least Squares.

[b] (I) refers to the use of tractor rental prices for $PK$ and (II) to a weighted average of all rental prices as discussed in the text.

[c] A single asterisk (*) denotes significance at the 5 percent level, a double asterisk (**) at the 10 percent level.

[d] $t$-values are in parentheses below each coefficient.

# Decision Making: The Role of Education*

WALLACE E. HUFFMAN

**In a dynamic environment with imperfect information, education contributes to production as an "allocative effect," arising from enhanced ability to acquire and process information efficiently, as well as a "worker effect." This study focuses on a single dimension of allocative ability: adjustment of Midwestern U. S. farmers to the changing optimum quantity of nitrogen fertilizer in corn production. Results support the hypothesis that rate of adjustment can be explained by economic variables; the rate is positively related to education of farmers, availability of information (agricultural extension), and scale incentive to be informed (acres of corn). Also, education and extension are substitute sources of allocative efficiency.**

*Key words:* **decision making; education; agricultural extension; information; nitrogen fertilizer; corn; allocative ability; adjustment.**

IN AN ENVIRONMENT of imperfect information Welch [28] has proposed that education contributes to production as an "allocative effect" as well as a "worker effect."[1] The worker effect refers to education's effect on technical efficiency, a more educated worker's ability to produce more output from a given bundle of inputs. The allocative effect is rooted in the decision-making process. It refers to the human agent's ability to acquire, decode, and sort market and technical information efficiently.[2] The assumption is that schooling augments skills that facilitate the gathering, processing, and interpreting of information, thereby enhancing allocative ability, reducing uncertainty, and contributing to efficient decision-making.[3] However, allocative skills have a comparative advantage over "rule-of-thumb" decision-making procedures *only* when it becomes necessary to learn and adjust to new opportunities. Disequilibria, resulting from advances in technology and changes in market conditions and yielding expected losses from ignorance (uncertainty), provide the economic incentives for human agents to learn and to adjust their activities. Consequently, allocative ability should be reflected in the rates at which decision-makers adjust their activities, given disequilibria.[4]

This study focuses on a single dimension of allocative efficiency: the adjustment of farmers to the change in the optimum quantity of a single input, nitrogen fertilizer, in corn production. Within the framework of a partial adjustment model with a variable adjustment coefficient, the rate of adjustment to disequilibrium in the usage of nitrogen fertilizer (between 1959 and 1964) is explained by economic variables. The rate of adjustment is positively related to the level of education of farmers

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1 In a world of perfect information, inefficiencies are pushed aside. All decision makers are perfectly informed; they are aware of the most efficient allocation of resources and best technology. Consequently, they all reach equally good profit maximizing solutions. However, when the assumption of perfect and costless information is relaxed, the prospect for inefficiencies emerges. Now a factor can contribute to production by improving technical and/or allocative efficiency and to entrepreneurship, viewed as a willingness to bear risk and cope with uncertainty, by reducing uncertainty.

2 Chaudhri [1], studying the contribution of education in Indian agriculture, first distinguished clearly between the worker and allocative effects of education. However, Nelson and Phelps [12] had earlier contended that education enhances innovative ability, one dimension of allocative ability.

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3 Stigler [20] argues that for each decision there is an optimum amount of information that corresponds to the quantity where the marginal expected return is equal to the marginal expected cost. Since information is costly, the optimum amount of information is a quantity that yields less than perfect knowledge. Also, Stigler [21] explicitly stresses the importance of the costs and returns to information when considering efficient resource allocation.

4 Schultz [19] emphasizes the importance of allocative ability under dynamic conditions of economic growth. He proposes that allocative ability is revealed in the rates that individuals are capable of adjusting their activities, given disequilibria. Nelson and Phelps [12] also contend that education is especially important for those functions requiring adaptation to change or learning.

(the decision-makers), the availability of information (extension), and the scale incentive to be informed (acres of corn). Some important implications of the study are: (1) that decision-makers with more education are able to grasp changes quickly and adjust more quickly and accurately to them; (2) that in a dynamic environment, the contribution of education to production via allocative ability is important—perhaps it is equal in value to the contribution of education via the worker effect; (3) that increasing the availability of information eases the gathering and processing of information; hence, the level of education of decision makers and the availability of information are directly related to allocative efficiency; and (4) that scale economies exist in using information.

The growth in fertilizer consumption has been an important source of advances in farm production. From 1950–54 to 1964 the quantity of nitrogen fertilizer annually applied to crops tripled in the U. S.; in Illinois, Indiana, Iowa, Minnesota, and Ohio—the states that provide the observations for the empirical analysis—nitrogen uses increased by fivefold during the period. Between 1959 and 1964, the price of nitrogen fertilizer fell from 10 to 15 percent (due partially to advances in the technology of nitrogen production) while corn prices increased 12 percent. New factors of production were introduced on a large scale (e.g., pesticides, especially herbicides, and more powerful and versatile tractors), and the quality of other factors of production and cultural practices (e.g., cropping rotations, plant populations, row widths) changed. By 1964 all hybrid seed corn varieties marketed in 1959 were replaced by new varieties that were more responsive to nitrogen. Hence the incentive to expand the use of nitrogen between 1959 and 1964 arises from *both* a change in relative prices and a change in technology.[5]

In section one the model is developed. The empirical analysis of fitting the model and interpreting the results is presented in section two. In section three implications are developed from the empirical analysis for the marginal product of education and extension from improved allocative efficiency. Section four presents the conclusions.

## The Model

The adjustment model consists of three equations: the fertilizer demand function (1), adjustment equation (2), and a variable adjustment coefficient (3). The model is

$$(1) \qquad X^*_t = D(W^*_t, T),$$

$$(2) \qquad X_t - X_{t-1} = \beta(X^*_t - X_{t-1}),$$

$$(3) \qquad \beta = B(Z),\ 0 < \beta < 1.$$

The demand for (optimum quantity of) nitrogen fertilizer per acre, $X^*_t$, is a function of a vector of "real factor prices" $W^*_t$ (expected and actual factor prices divided by the expected final product price), and a vector of environmental variables $T$, including education for the "worker effect." This specification of the demand function considers output and the other factors of production to be determined simultaneously with the use of nitrogen fertilizer; whereas, the prices, either expected or actual, are considered to be exogenous to the farmers' decisions.

The adjustment equation (2) specifies that the actual change in nitrogen fertilizer consumed between years $t$ and $t-1$ is equal to a proportion of the gap between the optimum quantity of nitrogen in year $t$ and the actual quantity consumed in year $t-1$. The adjustment coefficient $\beta$ measures the rate that farmers adjust the actual quantity of nitrogen fertilizer consumed to the optimum quantity. It is restricted to values between zero and one. If $\beta$ were unity, then adjustment would be complete within the relevant time unit—the actual quantity of nitrogen fertilizer consumed would be equal to the optimum quantity. If $\beta$ were zero, no adjustment would occur.

The model is unique in that the adjustment coefficient $\beta$ (3) is a function of a vector of economic variables $Z$.[6] The variable coefficient specification, opposed to the traditional constant coefficient of adjustment form [14, 13], permits an analysis of the effect of economic variables on the rate of adjustment to disequilibrium. More

[5] Griliches [3], using aggregate data for the U. S., concludes that the tremendous increase in fertilizer consumption during the period 1911 to 1956 can be largely explained by changes in relative prices when adjustment is not assumed to be instantaneous. He does not dismiss the importance of information for adjustment. He argues rather that it is endogenous. Learning is in response to changing relative prices.

[6] Griliches [4] analyzes differences in the rate of acceptance of a new input, hybrid corn. He found that the relative and absolute profitability of hybrid seed over open pollinated seed was the major explanation for differences in the rate of acceptance of the innovation from state to state. Phleps [16] employs a stock adjustment model with a variable adjustment coefficient for explaining state and local governmental capital outlays on highways.

specifically, $\beta$ is assumed to be a function of the following exponential type:

$$\beta = e^{b_0+b_1E+b_2EXT+b_3E\times EXT+b_4CACRES+b_5DE}, \tag{4}$$

with

$$\partial\beta/\partial E = (b_1 + b_3EXT)\beta, \tag{5}$$

$$\partial\beta/\partial EXT = (b_2 + b_3E)\beta, \tag{6}$$

$$\partial\beta/\partial CACRES = b_4\beta, \tag{7}$$

$$\partial\beta/\partial DE = b_5\beta, \tag{8}$$

where

$E$ = education of farmers,
$EXT$ = amount of contact between agricultural extension agents and farmers,
$CACRES$ = acres of corn per farm,
$DE$ = deviation of the actual $N$ consumed from the optimum $N$ in $t-1$, $X^*_{t-1} - X_{t-1}$,

and where (5)–(8) denote the respective partial derivatives of the adjustment coefficient.

Allocative ability presumably has a comparative advantage over "rule-of-thumb" decision-making procedures when it becomes necessary to learn and adjust to new opportunities. If the advantage associated with additional education refers to the differential ability to acquire and decode information, then farmers with more education presumably are aware of a wider range of information sources and are more efficient at processing information and reaching decisions. Hence, the hypothesis is that farmers with more education adjust faster to disequilibrium than farmers with less education, holding "other things equal" including economic incentives to respond in a dynamic environment.

The contact between agriculture extension agents and farmers is introduced as a measure of the availability of information about new and improved inputs and prices to farmers. The Agricultural Extension Service is one important source of information for farmers. It is part of a mammoth information system where information about prices, production techniques, and new inputs arising from the research of state agricultural experiment stations, state universities, and the USDA is disseminated. Hence, the hypothesis is that an increase in the extension activity of disseminating information increases the availability of information and the rate of adjustment.

Moreover, utilization of available information is almost certainly dependent on the level of education of decision-makers. If processing of information depends on skills created by education, then the contribution of extension (education) to the rate of adjustment will depend on the level of education (level of extension activity). The expected direction of the education-extension interaction effect is ambiguous. If the advantage associated with additional education refers to the differential ability to acquire and decode information and if extension agents serve mainly as decoders of technical information, then the activity of disseminating decoded information can substitute for increased schooling; or alternatively, increased education can substitute for increased extension. In this case the education-extension interaction effect will be negative. However, if the extension activity serves as a major source of undecoded technical information, then the activity of disseminating technical information will complement additional education. Farmers with more education who have more skills for decoding information will benefit relatively more from the extension activity, and the education-extention interaction effect will be positive.

The economics of information [20] imply that farmers are better informed about methods for producing more important than less important crops. The number of acres of corn per farm (*CACRES*) is introduced to capture the incentive of farmers to be informed about alternative factor combinations and appropriate scale of corn production, including the optimum quantity of nitrogen fertilizer. If the number of acres of corn is small, farm operators have a small incentive (i.e., small expected loss from ignorance) to be informed about the performance of new and improved factors of production, the optimum factor intensities, and the optimum scale of production. Alternatively, if farmers have a large number of acres of corn, then they have a greater incentive (i.e., larger expected loss from ignorance) to be informed about new and improved factors of production, optimum factor intensities, and the optimum scale of production. Hence, the hypothesis is that increasing the number of acres of corn per farm provides an incentive for a faster rate of adjustment.

The deviation of actual $N$ from optimum $N$ in the initial period may be important in determining the rate of adjustment. Farmers could be observed to have a large change between

1959 and 1964 because of a "catching-up" effect where a large change occurs because they were lagging badly in previous periods, then they improved their position relative to optimum. Alternatively, factors that were inhibiting adjustment to disequilibrium prior to 1959 could continue to inhibit adjustment during the period 1959 to 1964. Hence, to hold the size of the initial disequilibrium constant the variable $X^*_{t-1} - X_{t-1}$, the deviation of actual $N$ from the implied optimum $N$ in 1959, is added to the adjustment coefficient.

The demand function for nitrogen fertilizer is based on a generalized production function

$$(9) \qquad Y = A \prod_{i=1}^{n} X_i^{f_i(X)} e^{g(X)}$$

where $f_i(X)$ and $g(X)$ are functions of the vector $X$ of the factors of production. If $g(X) = 0$, then (9) is a Cobb-Douglas production function with variable elasticities of production [22, 2].

Specialize equation (9) to

$$(10) \qquad Y = AN^{\alpha_1} E^{a_2} W^{a_3} e^{\Sigma_j \delta_j D_j} \pi_i X_i^{a_i}$$

where

$Y$ = yield,
$N$ = nitrogen,
$E$ = education,
$W$ = an index of weather and natural endowment,
$D_j$ = geographical dummy variables,
$X_i$ = other factors of production.

The index of weather and natural endowment is a geometric form:

$$(11) \qquad W^{a_3} = R_1^{\gamma_1} R_2^{\gamma_2} GDD^{\gamma_3} Y_0^{\gamma_4}$$

where annual rainfall is split into the rainfall during two periods, all months excluding June, July, and August ($R_1$) and the months of June, July, and August ($R_2$), thereby allowing for the possibility of substitution or complementarity between rainfall in the two periods. $GDD$, accumulated growing-degree days, is a measure of accumulated heat units from a temperature range that is favorable to corn production [15, 18]. Hence, the effective length of growing season for corn is positively related to the accumulated number of growing-degree days. $Y_0$, the corn yield for a base year (1949) when little nitrogen fertilizer was applied to corn, is a proxy for the favorableness of the inherent soil characteristics—organic matter content, natural fertility, soil structure, and topography—for corn production.

The variable elasticity coefficient of $N$ is:

$$(12) \qquad \alpha_1 = a_1 + a_2(GDD \times R_2 \times Y_0).^7$$

It permits the interaction of nitrogen fertilizer with an index of environmental variables. Construction of the index as a product of growing degree days; rainfall during June, July, and August and base-year corn yield also allows for an interaction effect among the three environmental variables in determining the size of $\alpha_1$.

If

$$A' = A \, \pi_i X_i^{a_i},$$

then equation (10) specializes to a Cobb-Douglas production function with a variable elasticity of output for one input, $N$. For a maximum of the profit function to exist, it is required that

$$0 < \alpha_1 = a_1 + a_2\,(GDD \times R_2 \times Y_0) < 1.$$

Equating the marginal product of nitrogen to the expected price ratio of corn to nitrogen fertilizer and solving for $N$, the derived demand function for (the optimum quantity of) fertilizer is

$$(13)$$

$$\ln N^* = \left[\frac{1}{1-\alpha_1}\right] \left\{ \ln\alpha_1 + \ln A' + \alpha_2 \ln E + \alpha_3 \ln W + \Sigma_j \delta_j D_j - \ln\left[\frac{P^*_N}{P^*}\right] \right\}$$

where $P^*_N$ is the expected price of nitrogen, and $P^*$ is the expected price of corn. Empirical analysis of this model follows below.

## Empirical Analysis

In this section the production function is fitted to Midwestern U.S. county aggregate data for 1959 and 1964. The adjustment model is fitted between 1959 and 1964.

### The data

County aggregate data taken primarily from the *Census of Agriculture* and USDA publications are used for fitting the model. Unfortu-

[7] Polynomials of degree 2 in some and all of the variables, $GDD$, $R_2$, $Y_0$, and $E$, were also tried. However, based upon a goodness of performance criteria, including variables with statistically significant coefficients, large $R^2$, and reasonable predictions, the above environmental index performed the "best."

nately published data at the county level do not exist on the quantity of nitrogen fertilizer applied to corn. The *Census of Agriculture* estimates of the quantity of fertilizer applied to corn provide no indication of the nitrogen content (nor of the content of the other two primary nutrients). Consequently, the nitrogen content had to be estimated.

The basic procedure was as follows. First, the proportional nitrogen content of fertilizer applied to corn was estimated from available data for relatively homogeneous groups of counties, called state parts of agricultural subregions (SASR's) [10].[8] Second, the aggregate tons of $N$ applied to corn for each county were estimated by multiplying the tons of fertilizer applied to corn for each county [25] by the proportional nitrogen content for the SASR where the county was located.

A direct measure of the units of production information possessed by decision-makers does not exist. However, the *Census of Agriculture, 1964* provides (for the first time) county data for the number of farm operators in seven schooling completion classes, 0–4, 5–7, 8, 9–11, 12, 13–15, and 16 or more. Hence, an aggregate measure of the schooling of farmers, the decision-makers, can be constructed. Schooling is measured as a weighted average developed by applying Welch's income weights [29]: .25, .65, 1.00, 1.63, 2.26, 3.05, and 4.27, to the above respective schooling completion classes. In addition, unpublished Agricultural Extension Service data on the days allocated to crop production activities by state and federal extension staff permit the construction of a measure of the flow (or availability) of one important source of information about new and improved inputs and prices to farmers.

The basic unit of observation is the county. The principal criterion for including a county in the study area was that a large percentage of the farmers of a county (greater than 69 percent in 1964) engage in corn production.[9] The 306 countries from Illinois, Indiana, Iowa, Minnesota, and Ohio included in the study area represent the major corn growing areas of the Midwestern U.S. The model is estimated from a random sample of 122 of these counties (40 percent).

## Estimation of the production function

Production functions for 1959 and 1964 are estimated by fitting equation (10) to pooled cross-sectional data of county aggregate averages for 1959 and 1964.[10,11] All coefficients of the production function are unrestricted for the two years except $a_2$, the coefficient of the interaction variable between nitrogen and the environmental index; $\gamma_1$, the coefficient of annual rainfall excluding June, July, and August rainfall; $\gamma_2$, the coefficient of June, July, and August rainfall.[12] The geographical dummy variables, $D_j$'s, represent the relatively homogeneous groups of counties, state parts of agricultural subregions. The coefficients of the regional dummy variables are free to take different values for the two years and estimate the regional effects of the logarithmic intercept and the left-out factors of production, i.e., $\ln A' = \ln A + \Sigma_i \alpha_i \ln X_i$.

The results from fitting the production function are reported in Table 1. The function was fitted to 244 pooled observations of county aggregate average data, using classical least squares.[13] The coefficients have plausible signs; the $t$-ratios are large, at least for the non-dummy variables; and the $R^2$ is large, .79.[14,15]

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8 The estimates for 1964 were taken from a USDA publication on fertilizer use by Ibach and Adams [9] where estimates of the tons of fertilizer and of each primary nutrient applied to corn for all SASR's in the U. S. are presented. The estimates for 1959 were more difficult to obtain because Ibach and Adams failed to provide estimates of the tons of fertilizer applied to corn in their earlier fertilizer study [10].

9 See [8] for further details.

10 The fitted function is:

$$\ln Y = \ln A' + a_1 \ln N + a_2 (GDD \times R_2 \times Y_0) \times \ln N + \alpha_2 \ln E + \gamma_1 \ln R_1 + \gamma_2 \ln R_2 + \gamma_3 \ln GDD + \gamma_4 \ln Y_0 + \Sigma_j \delta_j D_j + \epsilon.$$

11 Application of classical least squares to pooled data may violate the assumption of homoscedasticity of the disturbances. When heteroscedasticity is present, the effect of applying classical least squares is to produce an inefficient estimator; however, the estimator continues to be unbiased.

12 Based upon a goodness of performance criteria, including variables with statistically significant coefficients, reasonable predictions, and large $R^2$, the above model performed the "best." Specifically, it performed better than an unrestricted model, i.e., one where two completely different production functions were estimated. The $R^2$ for the unrestricted model was .81.

13 Other functional forms were tried including quadratic and square root in $N$, but the above Cobb-Douglas specification performed "best."

14 At the sample's arithmetic mean for the variables, the implied marginal product of one year of schooling in corn production is 5.7 bushels of corn in 1959 and 5.5 bushels in 1964. Furthermore, at the sample's arithmetic mean price of corn of $1.04 per bushel in 1959 and $1.13 in 1964, the implied "own" (traditional) marginal value product of education in corn production is $5.93 per year of schooling in 1959 and $6.22 per year of schooling in 1964. Hence, between 1959 and

**Table 1. Estimates of the aggregate corn production function, Illinois, Indiana, Iowa, Minnesota, and Ohio, 1959, 1964**

| Independent Variables | 1959 | | 1964 | |
|---|---|---|---|---|
| | Coefficients | $t$-ratios* | Coefficients | $t$-ratios* |
| $N^a$ | .1971 | 3.130 | .2350 | 3.373 |
| $GDD \times R_2 \times Y_0 \times \ln N$ | −.00000652 | −2.156 | −.00000652 | −2.156 |
| $E^a$ | .4911 | 2.886 | .4247 | 2.330 |
| $R_1{}^a$ | −.2359 | −2.800 | −.2359 | −2.800 |
| $R_2{}^a$ | .4173 | 2.685 | .4173 | 2.685 |
| $GDD^a$ | .4887 | 1.667 | .8647 | 2.479 |
| $Y_0{}^a$ | 1.0003 | 6.111 | .9037 | 4.369 |
| $D_1{}^b$ | −2.050 | −1.396 | −2.050 | −1.396 |
| $D_{164}$ | | | −.9575 | −.590 |
| $D_2$ | −.3143 | −3.163 | −1.1858 | −.748 |
| $D_3$ | −.1823 | −1.497 | −1.0988 | −.683 |
| $D_4$ | −.0975 | −1.110 | −1.0939 | −.684 |
| $D_5$ | −.1364 | −1.477 | −1.3054 | −.818 |
| $D_6$ | −.0371 | −.727 | −1.0987 | −.675 |
| $D_7$ | .0190 | .269 | −1.0684 | −.652 |
| $D_8$ | −.0074 | −.108 | −1.1415 | −.706 |
| $D_9$ | −.1250 | −1.714 | −1.1481 | −.700 |
| $D_{10}$ | −.0447 | −.500 | −1.0708 | −.659 |
| $D_{11}$ | −.0322 | −.443 | −1.1176 | −.680 |
| $D_{12}$ | −.0965 | −1.236 | −1.0845 | −.657 |
| $D_{13}$ | −.1969 | −2.122 | −1.2192 | −.734 |
| $D_{14}$ | −.0869 | −.795 | −1.4521 | −.874 |
| $D_{15}$ | −.2066 | −1.761 | −1.0373 | −.625 |
| $D_{16}$ | −.1392 | −1.430 | −1.1820 | −.729 |
| $D_{17}$ | −.1537 | −2.189 | −1.3024 | −.801 |
| $D_{18}$ | −.2313 | −3.137 | −1.2335 | −.751 |
| $D_{19}$ | −.1823 | −2.701 | −1.3176 | −.813 |
| $D_{20}$ | −.2232 | −2.811 | −1.3336 | −.817 |

$R^2 = .790$ Degrees of Freedom $= 193$

* Ratio of coefficient to standard error.
[a] Variable enters the regression in the natural logarithmic form.
[b] State agricultural subregion (SASR) 71 in Iowa for 1959 serves as the base of reference for the intercept of the regression. The intercept for other regions, say region $i$, is estimated as the sum $\hat{\delta}_1 + \hat{\delta}_i$. The coefficient of $D_{164}$ estimates the change in the intercept for SASR 71 in Iowa between 1959 and 1964.

Definitions of Variables:

Dependent variable—Average corn yield in 1959 and 1964 is calculated as total bushels of corn harvested divided by total acres of corn harvested for grain from the Census of Agriculture [25] for respective years.

$N$—Average usage of nitrogen fertilizer is calculated as total pounds of commercial nitrogen fertilizer applied to corn divided by *Census of Agriculture* number of acres of corn for all purposes. Tons of nitrogen applied to corn are estimated as the *Census of Agriculture* number of tons of fertilizer applied to corn multiplied by an estimate of the nitrogen content (proportion) of commercial fertilizer for the state agricultural subregion where the county is located [8].

$E$—Education refers to a weighted average of the number (*Census of Agriculture, 1964*) of farm operators in seven schooling completion classes; hence the level of education of farmers in 1964 also serves as a proxy for their average level of education in 1959. The weights are from Welch [29] for 0–12 years and Welch unpublished, for 13–16+ years:

| | Years of Schooling | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0–4 | 5–7 | 8 | 9–11 | 12 | 13–15 | 16 |
| Weights | .25 | .65 | 1.00 | 1.63 | 2.26 | 3.05 | 4.27 |

$R_1$—Annual rainfall (inches) for the calendar year excluding June, July and August for the Weather Bureau District where the county is located. Actual precipitation data are from *Climatology Data* [27].

$R_2$—June, July and August rainfall (inches) is data for the Weather Bureau District where the county is located [27].

### Estimation of the adjustment equation

The parameters of the variable adjustment coefficient are estimated by fitting the adjustment function between 1959 and 1964 to the county aggregate average data. By substituting equation (4) into equation (2), taking the natural logarithm, and rearranging, the adjustment function is transformed into a form that is linear in the parameters of the adjustment coefficient and in a random disturbance:

$$(14) \quad \ln[(X_t - X_{t-1})/(X^*_t - X_{t-1})] = b_0 + b_1E + b_2EXT + b_3E \times EXT + b_4CACRES + b_5DE + u,$$

where $t = 1964$ and $t - 1 = 1959$. Equation (14) can be estimated by applying classical least squares.

Estimates of the optimum quantity of nitrogen for each county are obtained from the antilogarithm of equation (13). Parameters for the demand equation are taken from Table 1, and the prices for corn and nitrogen fertilizer are taken from Table 2. The values for $E$, schooling of farmers, and $Y_0$, base year (1949) corn yield, are a county's actual values for these variables. The values of $R_1$, annual rainfall excluding June, July, and August rainfall, and $R_2$, June, July, and August rainfall, are the 30-year normal (average) values for the Weather Bureau District where the county is located [23]. The value of $GDD$, accumulated growing degree days, is the normal (average) value [17].[16,17]

1964 there appears to be a slight increase in the value of the "worker effect" of education in this *one* farming activity, corn production.

[15] Results from fitting the above equation to pooled data with all dummy variables removed are similar. The signs of all the estimated coefficients are the same, all coefficients are statistically significant at better than the 1 percent level, and the $R^2$ is .60. However, the calculated and critical $F$ values are $F(39, 193) = 4.50 > F_{.01}(39, 193) = 1.70$ for the test of the joint null hypothesis that the coefficients of all dummy variables are zero. Hence, the null hypothesis is rejected; the dummy variables "belong" in the regression.

[16] The assumption is that farmers make production decisions for corn based upon expectations of normal weather conditions.

[17] The implied average optimal nitrogen levels and the average deviation of actual from implied optimal nitrogen levels by states for 1959 and 1964 are given in the table below.

The average deviation of actual from the implied optimal nitrogen levels far each state is larger in 1964 than in 1959. This finding is consistent with the relatively rapid change in the Midwest between 1959 and 1964 in hybrid seed corn varieties, including the introduction of single crosses, and in the cropping rotations, especially the push toward continuous corn. However, farmers in these five states have not remained idle in the face of such large deviations from optima in 1964. Between 1964 and 1969, the average total consumption of $N$ per acre of corn for all purposes [23] in the states of Illinois, Indiana, and Ohio increased by 51.7 percent (44 lbs. per acre) or an annual average of 10.3 percent and in the states of Iowa and Minnesota by 133.1 percent (70 lbs. per acre) or an annual average of 26.4 percent. Hence, both the percentage and absolute change between 1964 and 1969 in $N$ usage by Iowa

**Table to Footnote 17**

| States | Number of Sample Counties | Average Optimal $N$ Levels (lb/ac) 1959 | 1964 | Average Deviation of Actual from Optimal $N$ Levels (lb/ac) 1959 | 1964 |
|---|---|---|---|---|---|
| Illinois | 30 | 59.2 | 123.9 | 39.4 | 61.6 |
| Indiana | 19 | 71.2 | 127.9 | 39.5 | 70.4 |
| Iowa | 39 | 80.9 | 165.7 | 67.7 | 127.2 |
| Minnesota | 19 | 73.6 | 123.4 | 57.4 | 99.3 |
| Ohio | 15 | 62.4 | 108.4 | 31.3 | 44.1 |

**Table 1 notes, continued**

*GDD*—Accumulated growing degree days refer to normal growing degree days between 50 percent freeze probability dates [23]. Data are expressed in hundreds.

$Y_0$—Average base year corn yield is calculated as aggregate bushels of corn harvested divided by aggregate corn harvested for grain in 1949 [25].

$D_1$—Geographical dummy variables refer to state agricultural subregions (SASR's): $D_1$ ($D_{164}$)—Iowa SASR 71, North Central; $D_2$—Minnesota SASR 72, West Central; $D_3$—Minnesota SASR 71, Southwest; $D_4$—Minnesota SASR 57, Central Southeast; $D_5$—Minnesota SASR 56, East Central; $D_6$—Iowa SASR 70, Western; $D_7$—Iowa SASR 58, East Central; $D_8$—Iowa SASR 57, Northeast; $D_9$—Iowa SASR 59, South Central; $D_{10}$—Illinois SASR 57, Northwest; $D_{11}$—Illinois SASR 58, Northwest Central; $D_{12}$—Illinois SASR 51, Central, East Central; $D_{13}$—Illinois SASR 59, Southwest Central; $D_{14}$—Illinois SASR 60, Southwest; $D_{15}$—Illinois SASR 42, Southeast; $D_{16}$—Indiana SASR 52, Northwest; $D_{17}$—Indiana SASR 39, Northeast, North Central; $D_{18}$—Indiana SASR 38, Central; $D_{19}$—Ohio SASR 39, Northwest; $D_{20}$—Ohio SASR 38, West Central.

Table 2. Prices of corn and nitrogen fertilizer for selected states, 1959–64[a]

| States | Price of Corn ($/bu) 1959 | Price of Corn ($/bu) 1964 | Price of Nitrogen[b] (¢/lb) 1959 | Price of Nitrogen[b] (¢/lb) 1964 | Price of Nitrogen ÷ Price of Corn (bu/lb) 1959 | Price of Nitrogen ÷ Price of Corn (bu/lb) 1964 |
|---|---|---|---|---|---|---|
| Illinois | 1.08 | 1.14 | 8.9 | 7.6 | .082 | .067 |
| Indiana | 1.07 | 1.10 | 8.1 | 7.5 | .077 | .067 |
| Iowa | 1.02 | 1.16 | 8.9 | 7.8 | .087 | .068 |
| Minnesota | .95 | 1.08 | 9.5 | 9.0 | .101 | .083 |
| Ohio | 1.07 | 1.11 | 10.3 | 8.6 | .097 | .077 |

Sources: [18, 22].
[a] All reported prices are a weighted average of actual prices over three years: $P^*_t = .69P_t + .23P_{t-1} + .08P_{t-2}$.
[b] From anhydrous ammonia.

Two empirical measures of the availability of information are constructed from the unpublished Extension data, *EXT* and *EXTIH*. *EXT* is the fraction of all farm operators who were assisted by state and federal extension staff with the use of fertilizer on grain crops. It is a direct measure of the availability of information to farmers about the use of fertilizer on corn. *EXTIH*, the average time spent per farm by state and federal extension staff assisting farmers with grain crop production problems, is a broader measure of the availability of information about efficient corn production.[18] Which measure of available information will perform the best, the narrow and specific *EXT* or the broader *EXTIH* which includes the assistance of farmers with a diverse range of problems related to crop production?

The results from fitting equation (14) to the county aggregate average data are reported in Table 3. All coefficients have plausible signs, and the $R^2$'s are good. Regression equation (2) (Table 3), which includes *EXTIH*, has a larger $R^2$ than regression equation (1), which includes *EXT*; and all of the regression coefficients are statistically significant at better than the 5 percent level.[19] Also note that education and extension are individually and jointly significant. Hence, regression equation (2) is considered to be the "best" estimate of the adjustment function.

The important characteristic of these regressions, however, is the conformity of the signs of the estimated partial derivatives of the adjustment coefficient with expectations [equations (5)–(3)]. The expected signs of the partial derivatives and the estimated values of the partial derivatives for regression equation (2), evaluated at the sample's arithmetic mean values for education and extension, are presented in Table 4.

The positive partial derivative of education ($E$) supports the hypothesis that farmers with more education adjust faster to disequilibria than farmers with less education. The positive partial derivative for *EXTIH* supports the hypothesis that an increase in the contact between agricultural extension agents and farmers increases the rate of adjustment to disequilibria. The regression coefficient of the education–extension interaction ($E \times EXTIH$) is negative and statistically significant at better than the 5 percent level. The implication is that if education (availability of information, represented by extension) were increased, then the contribution of available information (education) to adjustment would be reduced. This suggests that an increase in the availability of information (i.e., extension) erodes or substitutes for some of the advantage associated with more education when adjusting to disequilibria. Or alternatively, an increase in the level of education erodes the contribution of information. The negative education-extension interaction effect is also consistent with the Agricultural Extension Service supplying primarily decoded technical informa- to farmers rather than undecoded technical information.

The positive and statistically significant coefficient (and partial derivative) of acres of corn per farm (*CACRES*) supports the hypothesis that farmers with more acres of corn adjust faster to disequilibria than farmers with fewer

and Minnesota farmers relative to the change by Illinois, Indiana, and Ohio farmers is consistent with the finding that Iowa and Minnesota farmers were much farther from optimal $N$ usage in 1964.

[18] The exact definitions of the variables appear in the notes to Table 3.

[19] The $R^2$'s of these regression equations should not be taken too seriously because they measure the fraction of the variation of the transformed dependent variable $\ln[(X_t - X_{t-1})/(X^*_t - X_{t-1})]$ that is "explained."

Table 3. Estimates of the adjustment function for nitrogen fertilizer between 1959 and 1964, Illinois, Indiana, Iowa, Minnesota, and Ohio

| Regression Equation | (1) | (2) |
|---|---|---|
| Coefficients of: | | |
| *E* | 1.629 | 2.080 |
| | (2.924)[a] | (3.279) |
| *EXT* | 4.374 | |
| | (1.547) | |
| *EXTIH* | | 1.959 |
| | | (2.075) |
| *E* × *EXT* | −2.438 | |
| | (−1.485) | |
| *E* × *EXTIH* | | −1.122 |
| | | (−2.059) |
| *CACRES* | .006 | .006 |
| | (2.759) | (2.642) |
| *DE* | −.020 | −.020 |
| | (−6.759) | (−6.636) |
| Constant | −3.834 | −4.572 |
| | (−3.821) | (−4.024) |
| $R^2$ | .414 | .422 |
| Degrees of freedom | 116 | 116 |

[a] *t*-ratios are in parentheses.

Definitions of variables:

*E*—Education. See definitions for Table 1.

*EXT*—Extension contact with farmers calculated as the average over 1958 and 1960 of the number of farmers and other individuals assisted by agricultural agents with the use of fertilizer on grain crops divided by the *Census of Agriculture, 1959* number of farm operators. Data for aggregate numbers assisted by county agents are taken from unpublished reports of the Federal Extension Service.

*EXTIH*—Extension contact with farmers calculated as: (average over 1958 and 1960 of the time in one-tenth hours devoted to crops by agents doing primarily agricultural work divided by average over 1958 and 1960 of the number of farmers and other individuals assisted with any phase of production of grain crops)$^{1/2}$ × (average over 1958 and 1960 of the number of farmers and other individuals assisted with any phase of production of grain crops divided by *Census of Agriculture, 1959* number of farm operators). The extension data are from unpublished reports of Federal Extension Service.

*CACRES*—Number of acres of corn per farm is calculated as the aggregate number of acres of corn for all purposes in 1964 divided by the aggregate number of farms in 1964 (*Census of Agriculture, 1964*).

*DE*—The deviation of the actual average consumption of nitrogen fertilizer from implied optimum in 1959 is calculated as the implied average optimum quantity in 1959 minus the average actual quantity consumed in 1959.

Table 4. Expected signs of the partial derivatives of the adjustment coefficient and their estimated values

| Partial Derivatives | Expected Sign | Estimated Values[a] |
|---|---|---|
| $\partial\beta/\partial E$ | + | $[2.080 - 1.122(1.017)]\beta = .839\beta$ |
| $\partial\beta/\partial EXT$ | + | $[1.959 - 1.122(1.735)]\beta = .013\beta$ |
| $\partial[\partial\beta/\partial E]/\partial EXT$ | ? | $-1.122\beta$ |
| $\partial\beta/\partial CACRES$ | + | $.006\beta$ |
| $\partial\beta/\partial DE$ | ? | $-.020\beta$ |

[a] $\beta$, equation (4), is always positive.

acres of corn. This points to scale economies in using information—the cost of $\beta \neq 1$ is higher for farmers with a large number of acres of corn than for farmers with a small number of acres of corn. It also suggests that farmers tend to be fairly well informed about efficient methods for "important" production activities even when their level of education is low and information is not readily available. However, this implies that they devote more time and effort to information acquisition and interpretation and less time to all other activities. Specifically, farmers with an above average number of acres of corn and a below average level of education will be closer to equilibrium than farmers with both below average number of acres of corn and level of education. To accomplish this, the former group must spend more time gathering and processing information than the latter group. However, farmers with both above average number of acres of corn and level of education will be closer to equilibrium than either of the above two groups and spend less time acquiring and analyzing information.

The regression coefficient of *DE*, $X^*_{t-1} - X_{t-1}$, is negative and significant at the 1 percent level. The implication is that factors which inhibited adjustment prior to 1959 were apparently inhibiting adjustment between 1959 and 1964. Hence, there is no evidence of a differential "catching-up" effect.[20]

[20] No simple statistical relationship between the dependent variable in (14) and *DE* exists. All unambiguous statements about their statistical correlation require strong *a priori* assumptions, and most require several strong assumptions. For example, if $X_t = X_{t-1}$, i.e., farmers use the same quantity of *N* in both years, then the statistical correlation between $[(X_t - X_{t-1})/(X^*_t - X_{t-1})]$ and $X^*_{t-1} - X_{t-1}$ is zero.

A related problem is the probable measurement error in the independent variable *DE*, arising from the

The question is whether the variable adjustment coefficient model performs significantly better than a constant coefficient of adjustment model, i.e.,

$$H_0: b_1 = b_2 = b_3 = b_4 = b_5 = 0.$$

Using regression equation (2), Table 3, the computed and critical $F$ values are $F(5,116) = 16.9 > F_{0.01}(5,115) = 3.18$. Hence, the null hypothesis is rejected that education, extension, acres of corn per farm, and distance of actual $N$ from the implied optimum $N$ do not jointly contribute to the explanation of adjustment to disequilibrium. Thus between 1959 and 1964, a variable adjustment coefficient model performs significantly better than a traditional constant coefficient of adjustment model for explaining adjustment of farmers to disequilibrium in the usage of one factor of production, nitrogen fertilizer.[21]

## Implications

This study shows a positive and significant relationship between adjustment to disequilibria and the level of education and the availability of information, represented by the extension activity. In particular, an increase in either the level of education or extension results in a movement toward equilibrium usage of $N$, i.e., an increase in their values always reduces the size of the disequilibrium gap, the difference between the marginal value product of $N(VMP_{N_t})$ and the price of $N(P_{N_t})$. Hence, for an increase in education or extension there is an allocative gain from selecting a "more correct" quantity of $N$ (see [28, p. 45)].[22] As a result, a measure of the marginal product of education (extension) from this allocative gain is

$$(15) \qquad (VMP_{X_t} - P_{X_t})\ \partial X_t/\partial V,$$

where

$$\partial X_t/\partial V = (X^*_t - X_{t-1})\ \partial\beta/\partial V, \qquad V = E, EXT.^{23}$$

The marginal product of education and extension, attributed to improved allocative efficiency, is estimated for a "typical county," a county whose variables take values at the sample's arithmetic mean. For these estimates the parameters of the adjustment coefficient are taken from (2), Table 3, and the parameters of the demand function are taken from Table 1. The estimate of the optimum quantity of nitrogen, $X^*_t$, is from the antilogarithm of (13).

If the average level of education of farmers were one year higher (an increase from 10 years to 11 years approximately) in 1959, then the quantity of nitrogen used on corn would have been 8.22 pounds per acre higher in 1964. In 1964 the estimated (average) size of the disequilibrium gap is \$.114 per pound of nitrogen, and the number of acres of corn harvested in 1964 per farm (farmer educated one additional year in 1959) is 55.2.[24,25] Hence in 1964, the estimated marginal product of an additional year of schooling arising from improved allocative efficiency is $(.114 \times 8.22 \times 55.2 =)$ \$52 per farm and farmer educated one additional year in 1959. Stated another way, the profit per farm would have been \$52 higher due to this

"implied" optima for $X^*_{t-1}$ being unequal to the "true" optima. However, if the measurement error for $DE$ is independent of the measurement error in the dependent variable, $\ln[(X_t - X_{t-1})/(X^*_t - X_{t-1})]$, arising from the implied optima for $X^*_t$ being unequal to the "true" optima, and of the "true" values of the independent and dependent variables respectively, then the size of the estimated coefficient of $DE$ will be biased toward zero, i.e., the marginal effect of $DE$ on the adjustment rate will be underestimated [11, p. 282].

21 The adjustment function was also fitted for the logistic form of the variable adjustment coefficient, i.e., $\beta = 1/[1 + \exp(Z'B)]$. The results from fitting this form, which automatically restricts the values of $\beta$ between zero and one, were nearly identical to the above results.

22 Havlicek and Seagraves [6] have estimated the value of additional information (cost of wrong decisions) from "better" decisions about the usage of nitrogen on corn in North Carolina.

23 Increasing education also increases the implied optimum quantity of nitrogen fertilizer. Hence the total allocative and joint worker-allocative effect on the actual quantity of nitrogen consumed is $\partial X_t/\partial E = (X^*_t - X_{t-1})\partial\beta/\partial E + \beta\partial X^*_t/\partial E$.

24 The average gap is calculated as $(\phi^0 + \phi^1)/2$ where $\phi^0$ represents the gap (difference) between the marginal value product of nitrogen and its price for the actual quantity consumed in $t$ and where $\phi^1$ represents the gap after the implied increase in the use of nitrogen caused by an extra year of education.

25 The author's view is that an increase of 8.22 pounds of $N$ per acre per year of schooling is not particularly large, given the deviation of actual from implied optimum $N$ of 103 pounds per acre (implied optimum of 151 pounds per acre). Certainly moderate increases in the education of farmers will perform no miracles in getting rid of the disequilibrium in $N$ usage. Furthermore, the order of magnitude of the disequilibrium gap for nitrogen (measured as $VMP$/factor price) of 2.66 (at the margin $VMP_N = \$.213$ per lb. and $P_N = \$.080$) in this study is consistent with the findings from state aggregate data by Griliches [5] and Headley [7]. Griliches' findings imply a disequilibrium gap for fertilizer (weighted primary plant nutrients), of 5 in 1949 and 2.7 in 1959. Headley's results imply a disequilibrium gap for fertilizer of 3.95 to 4.91 in 1963.

one dimension of improved allocative efficiency in the one farming activity, i.e., using nitrogen in corn production.[26]

To gain perspective, consider the implied annual average total marginal product of education in corn production for the allocative gains from better decisions about $N$ usage and the "worker effect." The annual average over the period 1959–64 (1) "own" (traditional) marginal value product is \$6.08 [(5.93 + 6.22)/2 from footnote 14]; (2) "pure" allocative effect is \$10.40 (\$52 assumed to be spread evenly over 5 years); and (3) joint worker-allocative effect is \$11.20 (\$108. — \$52. assumed to be spread evenly over 5 years—see footnote 26). Hence, the implied annual average total marginal product of education in corn production is \$27.68 (6.08 + 10.40 + 11.20) per farm, and the implied "pure" allocative effect of education from the $N$ fertilizer decision in corn production is 1.5 times as large as the "own" (traditional) marginal product of education. Since there appear to be other inputs in corn production where there are disequilibria, i.e., pesticides (see [7]), these findings suggest that the allocative effect of education in corn production in the U.S. is relatively very important.

For extension, if the time spent by federal and state extension staff assisting farmers with grain crop production problems were six minutes (one-unit) higher in 1959 (at the value of 8.64 units), the quantity of nitrogen used on corn would have been .025 pounds per acre higher in 1964. The estimated size of the disequilibrium gap is \$.133 per pound of nitrogen, and the number of acres of corn harvested is 97,730 acres per county. Seventy-four and three-tenths hours of extension staff time are required for the one-unit increase in extension time per farmer assisted in 1959 (a total of 1,770 farmers in 1959 and 42 percent assisted). Hence, in 1964 the estimated marginal product of 74.3 hours of extension time is \$322.50 per county or approximately \$4.48 per hour.

A reasonable estimate of the marginal cost of extension time in 1959 is \$4.20 per hour. This assumes an hourly wage for agricultural extension agents of \$2.82, the weighted average of 110 percent of the median income by states for males in the public educational services occupation [26, Table 130] deflated by 2,000 hours, plus travel expenses and costs of materials and auxiliary support equal to 9 percent and 40 percent respectively of the hourly wage. Hence, the social rate of return from extension time allocated to improving the nitrogen fertilizer decision in corn production is only 1.3 percent. However, agricultural extension presumably makes a positive net impact on other decisions in corn production (e.g., pesticide usage) and in the production of other crops, but the total marginal cost of agricultural extension time has been charged to the nitrogen fertilization of corn decision. Hence, 1.3 percent can be viewed as a *lower* bound on the social rate of return. For example, if the return from the nitrogen fertilization of corn decision were so large as 50 percent of the gross returns from agricultural extension in all production, then the social rate of return would be 16 percent. This suggests that public expenditures on agricultural extension have been providing a good payoff to society.[27]

## Conclusions

This research has focused on a single dimension of allocative efficiency: the rate of adjustment of farmers to the change in the optimum quantity of a single input, nitrogen fertilizer, in corn production. The results support the general hypothesis. Within the framework of a partial adjustment model with a variable adjustment coefficient, the rate of adjustment to disequilibrium in the usage of nitrogen fertilizer between 1959 and 1964 is explained by economic variables. Rate of adjustment is positively related to the level of education of farmers (the decision-makers), the contact between state and federal extension staff and farmers (availability of information), and the acres of corn per farm (scale). These results suggest the following:

(1) That decision-makers with more educa-

[26] The implied total increase in the consumption of nitrogen arising from an extra year of schooling is 17.23 pounds. The implied marginal product of an additional year of schooling from both improved allocative and joint technical-allocative efficiency is $(.114 \times 17.23 \times 55.2 =)$ \$108 per farm.

[27] These calculations assume that the value (price) of an additional unit of output (nitrogen) is equal to the market price, so it does not account for the reduction (possible increase) in the market price for corn (nitrogen) that would occur if all farmers in the U. S. simultaneously increased the consumption of nitrogen fertilizer and produced more corn because of an increase in the level of their education. Also, it does not account for the substitution effects among the demand for and the supply of other grain crops that would occur if the price of corn changed. In addition, it ignores income distribution effects that arise when the more educated farmers adjust faster and benefit more and when the less educated farmers adjust slower and are made worse off.

tion can more quickly grasp changes and adjust more quickly and accurately to them, i.e., allocative efficiency is related to the education of decision-makers. Hence, allocative ability appears to be a stronger analytic concept for evaluating decision-makers than the traditional concepts of "entrepreneurial capacity" or "managerial capacity."

(2) That an increase in the availability of information (agricultural extension) eases the gathering and processing of information when adjustment is required.

(3) That scale economies exist in using information.

(4) That education and agricultural extension are substitute sources of allocative efficiency. An increase in extension (an activity of disseminating decoded technical information) substitutes for some of the advantages associated with additional schooling. Hence, increased extension can reduce losses from ignorance that are associated with insufficient schooling. However, the optimum amount of extension will decline as farmers attain higher levels of education.

(5) That the allocative effect of education is economically important in a dynamic environment, perhaps more important than the traditional worker effect of education.

(6) That expenditures on state and federal extension staff time in the U.S. are providing a good although not spectacular social rate of return.

Furthermore, in the case of modern agriculture, which is continually adjusting to disequilibria, the research advances the stock of knowledge about how to increase the rate of adjustment and how to improve the efficiency of the adjustment process. In the case of developing countries, where economic growth can be viewed as continual process of change that requires learning and adjusting to a continual flow of new opportunities, the rate and efficiency of growth may be increased by increasing the level of education and availability of information. Finally, the implications of this research for the contribution of education to decision making in general are far reaching. Some are suggested by the following question: If a year of schooling is worth annually $21 per farm for the nitrogen-corn decision, how much is it worth in the selection of a spouse (wife)? Or an occupation?

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# *Short Articles and Notes*

## Alternative Measures of Supply Elasticities: The Case of São Paulo Coffee*

R. Gerald Saylor

**Nerlovian supply functions are fitted to post-World War II coffee data for São Paulo, Brazil. Supply shifts are permitted through the use of dummy variables, and recent specifications of irreversible functions are tested. The modified Nerlovian functions perform best from both the economic and statistical point of view.**

***Key words:*** **price elasticity; coffee; irreversible supply functions.**

RECENT DISCUSSION in this *Journal* has re-emphasized the difficulty of specifying agricultural supply functions and deriving statistically reliable estimates of price elasticity. Tomek [8] has shown that alternative deflators suggest a supply shift in the cotton data used by Nerlove [7] and that re-estimation of the supply function using dummy variables to account for this shift alters the conclusion regarding lagged responses. Wolffram [11] has criticized the technique developed by Tweeten and Quance [9, 10] to estimate irreversible supply functions and has specified an alternative procedure for making such estimates. The purpose of this note is to show how the above specifications alter the conclusions regarding the price elasticity of supply for one particular set of data, coffee in the state of São Paulo, Brazil.

### The Data

Data for this study are taken from the Instituto Brasileiro do Cafe's [3] area data for the state of São Paulo for the years 1947–1970 and the Instituto de Economia Agricola's [4] data on coffee prices received by farmers for the years 1945–1969. The price variable is a weighted average of the deflated prices received in the previous three years with the geometrically declining weights selected according to goodness of fit criterion. The resulting data plotted in Figure 1 reveal a rapid expansion of coffee area after 1948 in response to price increases stimulated by the cessation of World War II and the advent of the Korean War. Price declines in the late 1950's and early 1960's were followed by a decline in the area planted in coffee, but as Figure 1 indicates, the decline until 1962 appears to be more sluggish than when prices were increasing. In 1962 the Brazilian government began the first of two coffee eradication programs terminating in 1967; the programs resulted in the removal of nearly 40 percent of São Paulo's coffee area.[1] This data set thus appears well-suited to test the sensitivity of the price elasticity of supply utilizing various specifications of the supply function.

### The Models

The empirical section of this note will test four basic specifications of the supply function. Nerlove's distributed lag function, of course, takes the following form:

$$A_t = a_0 + a_1 A_{t-1} + a_2 P_{t-1} + a_3 T + a_4 P_{t-1}{}^c + u_t$$

where

$A_t$ = coffee area planted as of July 1, in thousands of hectares,

$A_{t-1}$ = $A_t$ lagged one year,

$P_{t-1}$ = deflated price of coffee received by farmers (deflated by the Getulio Vargas Foundation's index number 2)[2] averaged over the three previous

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[1] Despite relatively high prices for the 1964 and 1965 observations, area planted in coffee continued to fall. This reflects the influence of the eradication program and the possible reluctance of farmers to plant coffee in the turbulence following the Revolution of 1964.

[2] Index number 2 of the Getulio Vargas Foundation is the most general wholesale price index published for Brazil. Alternative deflators such as the price index of 20 leading agricultural commodities in São Paulo (ex-

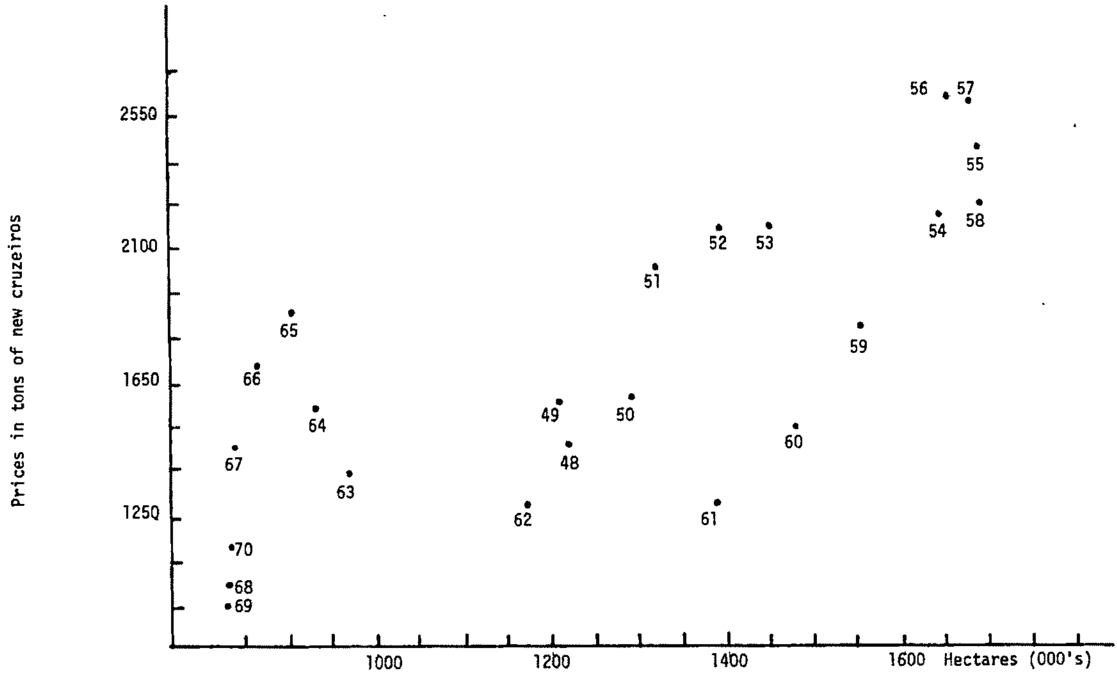


**Figure 1. Coffee hectares as of July 1 related to lagged coffee prices, 1948–1970**

years using declining geometrical weights,

$T$ = time trend,

$P_{t-1}{}^{c}$ = price index of 20 leading agricultural commodities[3] in São Paulo (excluding coffee) lagged one year, in constant terms,

and

$u_t$ = random disturbance term.

The above Nerlovian formulation is then modified by including a dummy variable to account for the rapid supply shifts that occurred during the six years of the coffee eradication program. Tomek's specification is then tested by inserting dummy variables to permit intercept and slope variations in the supply function for the two time periods: 1948–1962 and 1963–1970. This is done with and without the distributed lag term to ascertain its importance.

Fixed asset theory suggests that farmers may be less responsive to price decreases than to price increases since many agricultural inputs have a wide divergence between their acquisition price and their salvage value [5, 6]. In the case of coffee, the acquisition price is high since the farmer must plant and maintain new trees from three to five years before deriving any income from them. The salvage value, however, is quite low, as the alternative usage of felled coffee trees is limited to the provision of firewood and other such uses, and the cost of obtaining even this salvage value is high. As a result, resources may be committed to coffee production during boom periods, e.g., the Korean War, and remain locked into coffee production when prices decline.

Given that the fixed asset theory implies irreversible supply functions, Tweeten and Quance split the price variable in the following manner to test for different reactions to rising and falling prices:

$$A_t = a_0 + a_1 A_{t-1} + a_2 P^{I}{}_{t-1} + a_3 P^{D}{}_{t-1} + \ldots u_t$$

where

$P^{I}{}_{t-1}$ = actual lagged price when $(P_{t-1} - P_{t-2}) > 0$,
= 0, otherwise;

cluding coffee) and the index of wage rates paid to daily hired labor in São Paulo agricultural areas (such wages constituted between 50 and 60 percent of coffee production costs in the period studied) were attempted but caused little, if any, modification in the results.

[3] This variable attempts to see whether the prices of competing activities can influence area planted. If the fixed asset theory holds, one would expect little relation between this variable and acreage planted. However, if farmers switch into and out of coffee and other crops readily, then one would expect a negative relationship to hold between this price index and area planted in coffee. Studies made during the eradication program found that farmers shifted former land into a wide variety of activities. For this reason, the 20 commodity index was adopted.

and

$P^D{}_{t-1}$ = actual lagged price when $(P_{t-1} - P_{t-2}) < 0$,
$= 0$, otherwise.

Wolffram in his comment on the Tweeten and Quance paper demonstrated that their procedure for estimating irreversible functions was incorrect and leads to estimates of the two price parameters that are not significantly different statistically. Preliminary estimates with the São Paulo coffee data confirmed this bias, and the results are not repeated here. In Wolffram's formulation of the irreversible function, the price increase or decrease is added to any positive number (Wolffram prefers the price at the beginning of the period) to form a split-price variable whose values are either stationary or increasing. The Wolffram model takes the following form:

$$A_t = a_0 + a_1P^I + a_2P^D$$

where $P^I$ and $P^D$ depend upon the accumulated sum of first differences $(P_t - P_{t-1})$, or $\Delta P$, in the following manner:

$$
\begin{aligned}
P^I{}_{t-1} &= P_{t-1}\\
P^I{}_t &= P_{t-1} + \Phi(P_t - P_{t-1})\\
P^I{}_{t+1} &= P^I{}_t + \Phi(P_{t+1} - P_t)\\
&\vdots\\
P^I{}_{t+n} &= P^I{}_{t+n-1} + \Phi(P_{t+n} - P_{t+n-1})
\end{aligned}
$$

where

$P_t$ = initial year price observation
$\Phi = 1$ if $\Delta P \geqq 0$,

and

$\Phi = 0$ if $\Delta P \leqq 0$.

Similarly, $P_t{}^D$ can be defined in an analagous manner.

As can be seen from the above formulation, Wolffram's increasing and decreasing price variables take values which are either stationary or increasing. If, as expected, falling prices lead to fewer planted hectares, then the coefficient of the decreasing price variable will take the "wrong" sign, negative, requiring the reversal of the sign in order to compare it with the coefficient of the increasing price variable.

## The Empirical Results

The following notation will be used in this section:

$A_t$, $A_{t-1}$, $P_{t-1}$, $T$, $P_{t-1}{}^c$, and $u_t$ are as previously defined,

$D_E$ = dummy variable taking values of one during the six years of the coffee eradication program, 1962–1967, and zero in all other years,

$D_I$ = dummy variable to account for changes in intercept between the periods 1948–1962 and 1963–1970,

$D_s = D_I \cdot P_{t-1}$. This variable permits a change in the slope of the supply function for the years 1963–1970,

$P_{t-1}{}^I$ = price variable denoting increasing prices as defined by Wolffram,

$P_{t-1}{}^D$ = price variable denoting decreasing prices as defined by Wolffram,

and

$D_c$ = dummy variable to allow for intercept changes when the price variable is split into rising and falling segments.

### Reversible functions

Table 1 presents the regression results for the usual specification of the Nerlovian model and alternative specifications using systems of dummy variables to permit intercept and/or slope changes. The first two equations in arithmetic and logarithmic form respectively demonstrate that the Nerlovian model can explain most of the variation in coffee area observed over time ($R^2 = 0.961$ and $0.971$) with all coefficients taking the expected sign and being significant at either the 0.01 or 0.05 level.[4] The price elasticities, evaluated at the means for the arithmetic equation, are relatively low and indicate inelastic responses to price changes in both the short and the long run. Given the three- or four-year gestation period for newly-planted coffee and the loss in future income from coffee removal, this result is not unexpected.[5]

In equations (3) through (5) of Table 1, the standard Nerlovian model is modified by inserting a dummy variable, $D_E$, into the equa-

[4] Although the distribution of the Durbin-Watson statistic is as yet unknown and biased toward the value 2 for equations containing lagged dependent variables and a small number of observations, the results are presented for purposes of comparison with equations not containing the lagged dependent variable.

[5] For example, M. J. Bateman [2] found the highest price elasticity for Ghanaian cocoa to be 0.40. Similarly, M. Arak [1, p. 220] estimated that "a 1 percent change in the level of price expectations produced a change of approximately 6.5 million in the desired coffee tree stock in the state of São Paulo. This was estimated using data from 1933–1950. Since the average number of trees in existence during this period was 1,200 million, the implied price elasticity was very low.

Table 1. Coffee area response relationships for the state of Sao Paulo, Brazil, 1948–1970[a]

| Equation | Constant | $A_{t-1}$ | $P_{t-1}$ | $P_{t-1}{}^{e}$ | $T$ | $D_E$ | $D_s$ | $D_I$ | Short-run Elas- ticities | Long-run Elas- ticities | $R^2$ | Degrees of Freedom | D.W. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 709.635 | 0.813 | 0.085 | —5.501 | —5.829 | | | | .117 | .625 | .961 | 18 | 1.990 |
| | | (11.396) | (2.076) | (—2.653) | (—2.149) | | | | | | | | |
| (2)[b] | 1.253 | 0.841 | 0.101 | —0.532 | —0.002 | | | | .101 | .635 | .971 | 18 | 2.143 |
| | | (13.363) | (2.048) | (—3.358) | (—2.266) | | | | | | | | |
| (3) | 143.136 | 0.745 | 0.116 | 0.251 | —2.613 | —130.892 | | | .160 | .627 | .969 | 17 | 1.800 |
| | | (10.278) | (2.884) | (0.076) | (—0.900) | (—2.128) | | | | | | | |
| (4) | —36.462 | 0.750 | 0.129 | 1.492 | | —159.688 | | | .178 | .712 | .968 | 18 | 1.731 |
| | | (10.408) | (3.464) | (0.500) | | (—3.056) | | | | | | | |
| (5) | 100.341 | 0.764 | 0.125 | | | —139.437 | | | .173 | .733 | .968 | 19 | 1.758 |
| | | (11.781) | (3.500) | | | (—4.309) | | | | | | | |
| (6) | 988.762 | | 0.237 | | | | | —438.712 | | .327 | .841 | 20 | 1.012 |
| | | | (4.295) | | | | | (—7.892) | | | | | |
| (7) | 827.071 | | 0.262 | | 14.074 | | | —586.615 | | .362 | .920 | 19 | 1.844 |
| | | | (5.313) | | (2.638) | | | (—7.872) | | | | | |
| (8) | 707.316 | 0.715 | 0.105 | —4.687 | —2.635 | | | —85.614 | .144 | .505 | .962 | 17 | 1.936 |
| | | (4.356) | (2.053) | (—1.928) | (—0.478) | | | (—0.669) | | | | | |
| (9) | 686.889 | 0.660 | 0.119 | —4.193 | | | | —138.583 | .164 | .482 | .962 | 18 | 1.920 |
| | | (5.713) | (2.962) | (—1.948) | | | | (—2.215) | | | | | |
| (10) | 314.607 | 0.614 | 0.125 | | | | | —173.940 | .172 | .445 | .954 | 19 | 1.381 |
| | | (5.068) | (2.906) | | | | | (—2.712) | | | | | |
| (11) | 564.519 | 0.672 | 0.132 | —3.254 | —1.918 | | —0.086 | —11.253 | .182[c] | .554[c] | .964 | 16 | 1.922 |
| | | (3.862) | (2.140) | (—1.073) | (—0.340) | | (—0.806) | (—0.064) | .063[d] | .192[d] | | | |
| (12) | 275.259 | 0.589 | 0.164 | | | | —0.155 | 45.880 | .226[c] | .551[c] | .961 | 18 | 1.693 |
| | | (5.135) | (3.591) | | | | (—1.849) | (0.344) | .012[d] | .030[d] | | | |
| (13) | 471.069 | | 0.306 | 2.718 | 13.345 | | —0.212 | —274.538 | .130[d] | .423[c] | .930 | 17 | 1.815 |
| | | | (5.408) | (0.773) | (2.459) | | (—1.541) | (—1.270) | | | | | |
| (14) | 775.179 | | 0.295 | | 12.829 | | —0.156 | —342.168 | .192[d] | .407[c] | .928 | 18 | 1.753 |
| | | | (5.458) | | (2.409) | | (—1.349) | (—1.752) | | | | | |
| (15) | 902.079 | | 0.282 | | | | —0.204 | —135.732 | .108[d] | .389[c] | .904 | 19 | 1.029 |
| | | | (4.688) | | | | (—1.603) | (—0.691) | | | | | |

[a] Values in parentheses are $t$-values.
[b] Estimated in logarithms.
[c] Price elasticity for period 1948–1962.
[d] Price elasticity for period 1963–1970.

tion in order to account for the subsidized eradication of coffee between 1962 and 1967. This variable is significant in each of the three equations and takes a negative sign denoting a diminution of area each year of the program. Introduction of this variable, however, results in the loss of significance for both the $P_{t-1}{}^{c}$ and the $T$ variables. Both these variables are dropped in equation (5), and the remaining three variables are significant at the 0.01 level and explain 96.8 percent of the variation. The lagged dependent variable remains highly significant even in the presence of the dummy variable, although its coefficient is somewhat reduced.

The empirical results from Tomek's study suggest the need for further testing of the conclusion that a significant distributed lag exists when shifts in the supply function occur, such as the one depicted in Figure 1. To account for this shift and to assess the impact of changing the model specification, equations (6) through (15) were estimated. In all of these equations, the dummy variable, $D_E$, used in equations (3) through (5) was replaced by dummy variable $D_I$ which includes all the years after 1962 rather than just the six years of the eradication program.

In equations (6) and (7) of Table 1, the distributed lag variable was dropped. The results for equation (6), which includes only the lagged coffee price variable, $P_{t-1}$, and the dummy variable, $D_I$, show that both these variables are significant at the 0.01 level, but the Durbin-Watson statistic indicates positive serial correlation in the residuals. Since equation (6) appears to be misspecified, the trend variable, $T$, was introduced in equation (7). The residuals are no longer autocorrelated, $P_{t-1}$ and $D_I$ remain significant at the 0.01 level, $T$, is significant at the 0.05 level, and these three variables account for 92 percent of the variation of $A_t$. Equation (7) thus appears to be a reasonable alternative specification of the São Paulo coffee supply function and yields a price elasticity estimate about midway between the short- and long-run elasticities derived from the simple Nerlovian model.

In equations (8) through (12) of Table 1, the distributed lag variable is reintroduced; but in contrast to Tomek's results, this variable remains highly significant, and the hypothesis of a zero parameter for this variable in the presence of the supply shift factor is rejected. In fact, the dummy variable, $D_I$, is not significant in equation (8) and only becomes significant when the trend variable, $T$, is eliminated [equation (9)]. It will also be noted from Table 1 that the respecification of the dummy variable results in a further reduction of the coefficient of the lagged dependent variable, but the coefficient of the price variable is relatively unchanged. Short-run price elasticity thus remains constant while long-run elasticity is considerably reduced from the elasticity estimated from the simple Nerlovian formulation.

In equations (11) through (15) of Table 1, an attempt was made to permit both a slope and an intercept change in the supply function. When the lagged area variable is included [equations (11) and (12)], neither the slope nor the intercept variable is significant. When $P_{t-1}{}^{c}$ and $T$ are removed from the regression [equation (12)], $D_s$ is significant at the 0.10 level, but $D_I$ is not significantly different from zero. Inspection of the elasticities reveals a considerable reduction in both the short- and long-run elasticities in the 1962–1970 period. This confirms the visual impression from Figure 1 and suggests an upward bias in estimates not accounting for these supply shifts. In equations (13) through (15), an attempt was made to ascertain the impact of the lagged dependent variable. When the distributed lag term is excluded from the regressions, neither the slope nor intercept dummy variables remain significant even after the trend and competing price variables are removed. The Durbin-Watson statistic now lies in the inconclusive area, although removal of variable $T$ in equation (15) reintroduces autocorrelation. Results from equations (11) through (15) do not support the hypothesis that no lag exists. Inclusion of supply shift variables modifies slightly the estimation of speed of adjustment over time, but the evidence strongly supports the existence of a lagged adjustment process.

## Irreversible functions

The price variable, $P_{t-1}$, which assumes that the supply function is reversible, was next split into $P_{t-1}{}^{I}$ (increasing prices) and $P_{t-1}{}^{D}$ (decreasing prices) in order to test whether the apparent irreversible nature of the coffee data plotted in Figure 1 could be empirically estimated. The estimation was done utilizing the technique recently outlined by Wolffram. When all observations between 1948 and 1970 were included in the regressions, the results indicated: (1) high multicollinearity between the split-

price variables (simple correlation between the two price variables exceeded 90 percent); (2) positive serial correlation of the residuals when only the split-price variables were included in the regressions; (3) only the distributed lag term being significant when this term was included in the regression; and (4) highly unstable coefficients for the price variables when other terms were added to the regression. Due to these problems which remained even when dummy variables were used to account for the supply shifts, the years 1963 through 1970 were excluded from the analysis. The modified results are presented in Table 2.

To establish comparable data bases, the simple Nerlovian equations were re-estimated for the 1948–1962 period, and these results are shown as equations (1) through (3) in Table 2. The price index of competing crops is not significant in any of these regressions and always has the wrong sign (as it does for all estimates for the subperiod, 1948–1962). Coffee price and the distributed lag term remain the most important variables, but the distributed lag variable is highly correlated with the trend term, $T$. When these two variables are simultaneously included in equation (3), none of the variables retains statistical significance. Equation (2) thus appears to be the best Nerlovian specification and yields a short-run price elasticity virtually unchanged from earlier estimates. Long-run price elasticity, however, is considerably lower.

Wolffram's formulation of the irreversible supply function is tested in equations (4) through (7) of Table 2. When only the split-price variables are in the regressions, the technique yields results conforming to theoretical expectations: nearly 80 percent of the variation in coffee area is explained; both price variables are significant at the 0.01 level with each variable taking the expected sign; the Durbin-Watson statistic indicates no problem of serial correlation; and the price elasticity for rising prices is nearly three times larger than the price elasticity for falling prices. Also encouraging is the absolute size of the price elasticity for rising prices which exceeds the Nerlovian long-run elasticity [equation (2)] by 15 percent. Attempts to reduce the unexplained variation further were not successful. When the index of competitive prices and the time trend were introduced, the coefficient for the rising price variable became negative but not significant, and the elasticity of the falling price variable expanded to almost the level of the rising price elasticity of equation (4). In equation (6) the distributed lag term replaced the trend term, but none of the coefficients are significant at the 0.05 level, and the absolute values of the price coefficients are nearly identical. Finally, the dummy variable term suggested by Tweeten and Quance [9, p. 359] was introduced in equation (7) but did not improve the results. Again, the coefficients of the price variables are virtually identical with the falling price coefficient slightly exceeding that of the rising price term. None of the coefficients, however, is significant at the 0.05 level.

## Conclusions

The simple Wolffram model incorporating only the increasing and decreasing price variables conforms to theoretical expectations when data from 1963–1970 are excluded. Attempts to improve the estimates by including other variables normally used in supply analysis, however, were unsuccessful. Thus, while partial success was achieved in estimating Wolffram's irreversible supply function, a number of statistical problems arose which cast some doubts upon the technique. Wolffram's technique appears to have a built-in bias towards multicollinearity. If prices are alternatively rising and falling year by year, multicollinearity may be unavoidable. The Wolffram technique may yield satisfactory statistical results only when prices are either rising or falling over reasonably long periods of time, say four to five years.

Inclusion of the lagged dependent variable in the Wolffram model seems questionable. This term, which summarizes the state of the production process, permits farmers to close part of the gap between desired and actual plantings and, in effect, hypothesizes that the supply function is reversed. When this term enters the model, the coefficients of the split-price variable tend to equalize. However, when the lagged dependent variable was omitted and all the data (1948–1970) used, the presence of positive serial correlation indicated the function was misspecified. The statistical results of this study thus give only limited support to Wolffram's formulation of the supply problem.

Regarding reversible functions, the simple Nerlovian model and the Nerlovian model modified to allow for supply shifts performed well. An alternative specification which excluded the distributed lag term [equation (7)] also per-

Table 2. Coffee area response relationships for the state of Sao Paulo, Brazil, 1948–1962[a]

| Equation | Constant | $A_{t-1}$ | $P_{t-1}$ | $P_{t-1}{}^{c}$ | Wolfram $P_{t-1}{}^{I}$ | $P_{t-1}{}^{D}$ | $T$ | $D_c$ | Short-run elasticity | Long-run elasticity | Increasing price elasticity | Decreasing price elasticity | $R^2$ | Degrees of Freedom | D.W. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1)[b] | 1.282 | | 0.266 (4.083) | 0.464 (1.281) | | | 0.095 (4.835) | | | 0.266 | | | .843 | 10 | 1.62 |
| (2)[b] | 0.032 | 0.709 (5.421) | 0.149 (2.192) | 0.198 (0.608) | | | | | .149 | 0.512 | | | .867 | 10 | 1.62 |
| (3) | 27.340 | 0.511 (1.451) | 0.148 (1.660) | 3.429 (0.654) | | | 6.704 (0.5686) | | .196 | 0.401 | | | .851 | 9 | 1.53 |
| (4) | 903.125 | | | | 0.376 (6.251) | −0.170 (−3.168) | | | | | .591 | .212 | .785 | 11 | 1.57 |
| (5) | 1969.487 | | | 1.297 (0.224) | −0.086 (−0.304) | −0.438 (−7.787) | 82.369 (1.745) | | | | −.135 | .546 | .856 | 9 | 1.57 |
| (6) | 99.981 | 0.600 (1.644) | | 3.337 (0.612) | 0.157 (1.007) | −0.116 (−1.872) | | | | | .247 (.617)[c] | .145 (.362)[c] | .852 | 9 | 1.60 |
| (7) | 303.592 | 0.631 (1.708) | | 2.186 (0.388) | 0.124 (0.768) | −0.133 (−2.039) | | 52.155 (0.917) | | | .195 | .166 | .866 | 8 | 1.81 |

[a] Values in parentheses are $t$-values.
[b] Estimated in logarithms.
[c] Implied long-run elasticities.

formed well. However, in contrast to Tomek's findings, the inclusion of supply shifters in the model does not change the conclusion about lagged responses. The distributed lag term remains significant in all specifications which included various supply shifters.

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## APPENDIX

The original data used in this study appear in the Table below. To conserve space, only the basic data are presented. All the variables used in this study may be derived from this

**Appendix Table 1. Original data used in study**

| Year | $A_t$ (1000's of hectares) | Average Producer Price per ton in Current Cr$ | Daily Wage Rate 1969 = 1.00 | Index 2 Getulio Vargas Foundation 1969 = 1.00 | 20 Ag. Commodities São Paulo 1969 = 1.00 | $D_E$ | $D_I$ | Index of Prices Paid by São Paulo Farmers 1969 = 1.00 |
|---|---|---|---|---|---|---|---|---|
| 1945 | | 3.53 | 0.0028 | 0.0029 | | | | 0.0030 |
| 1946 | | 7.42 | 0.0034 | 0.0034 | | | | 0.0035 |
| 1947 | 1258.5 | 7.54 | 0.0041 | 0.0042 | 108 | | | 0.0044 |
| 1948 | 1214.5 | 7.42 | 0.0040 | 0.0047 | 109 | 0 | 0 | 0.0049 |
| 1949 | 1203.6 | 9.60 | 0.0045 | 0.0050 | 106 | 0 | 0 | 0.0051 |
| 1950 | 1286.7 | 18.17 | 0.0055 | 0.0056 | 100 | 0 | 0 | 0.0054 |
| 1951 | 1316.9 | 17.00 | 0.0068 | 0.0066 | 100 | 0 | 0 | 0.0061 |
| 1952 | 1392.8 | 17.67 | 0.0078 | 0.0074 | 102 | 0 | 0 | 0.0068 |
| 1953 | 1443.4 | 22.00 | 0.0083 | 0.0085 | 111 | 0 | 0 | 0.0079 |
| 1954 | 1644.6 | 36.67 | 0.0095 | 0.0107 | 101 | 0 | 0 | 0.0107 |
| 1955 | 1686.7 | 35.50 | 0.0118 | 0.0126 | 107 | 0 | 0 | 0.0129 |
| 1956 | 1650.9 | 38.00 | 0.0138 | 0.0150 | 107 | 0 | 0 | 0.0158 |
| 1957 | 1575.1 | 39.33 | 0.0158 | 0.0171 | 103 | 0 | 0 | 0.0181 |
| 1958 | 1583.7 | 28.67 | 0.0176 | 0.0194 | 100 | 0 | 0 | 0.0206 |
| 1959 | 1552.1 | 32.17 | 0.0219 | 0.0268 | 99 | 0 | 0 | 0.0308 |
| 1960 | 1478.3 | 43.17 | 0.0287 | 0.0346 | 110 | 0 | 0 | 0.0393 |
| 1961 | 1385.9 | 59.50 | 0.0372 | 0.0474 | 115 | 0 | 0 | 0.0528 |
| 1962 | 1172.1 | 102.17 | 0.0561 | 0.0718 | 124 | 1 | 0 | 0.0802 |
| 1963 | 963.7 | 208.33 | 0.0911 | 0.1260 | 116 | 1 | 1 | 0.1431 |
| 1964 | 927.6 | 520.00 | 0.1924 | 0.2400 | 114 | 1 | 1 | 0.2557 |
| 1965 | 903.6 | 500.00 | 0.3448 | 0.3765 | 105 | 1 | 1 | 0.4370 |
| 1966 | 860.2 | 504.83 | 0.4501 | 0.4193 | 115 | 1 | 1 | 0.5358 |
| 1967 | 831.0 | 677.97 | 0.6277 | 0.6666 | 100 | 1 | 1 | 0.6549 |
| 1968 | 831.3 | 1000.00 | 0.8277 | 0.8281 | 95 | 0 | 1 | 0.8414 |
| 1969 | 831.3 | 1692.84 | 1.0000 | 1.0000 | 100 | 0 | 1 | 1.0000 |
| 1970 | 831.3 | 2426.33 | 1.2934 | 1.1979 | 95 | 0 | 1 | 1.2034 |

data set. Also included in the Table is an index published by the Instituto de Economia Agricola [4, p. 86] of prices paid by farmers. This index includes machinery, fertilizers, sprays, vaccines, fuel, agricultural implements, feed costs, maintenance costs, and costs of services. Since most of the coffee farmers' costs relate to labor, this index was considered inappropriate. A comparison of this index with the daily wage rate and Indice No. 2 of the Getulio Vargas Foundation shows that the prices paid index tended to rise much more rapidly than the other two. Data for average producer coffee price, daily wage rate, and price index for 20 agricultural commodities (excluding coffee) are taken from [4]. Hectares planted comes from [3], and Index 2 of the Getulio Vargas Foundation has been taken from various issues of *Conjuntura Economica* published by the Foundation. This data set gives readers an opportunity to try other specifications of the model and construct alternative measures of the variables.

# Canadian Supply Functions for Livestock and Meat*

PETER TRYFOS

**A model is developed by which the interdependence between livestock supply and inventories is clarified. Data for 1951 to 1971 were used to obtain 3SLS estimates of Canadian supply and stock formation functions for cattle, calves, sheep and lambs, and pigs. Sensitivity of meat production to price and feed cost changes was examined.**

*Key words:* **Canadian; econometric; livestock supply; livestock inventories; meat production.**

MANY STATISTICAL STUDIES of demand for livestock have been published; statistical studies of supply are not so numerous. Among recent econometric studies of the livestock sector in which supply considerations are taken explicitly into account, supply functions are formulated in various ways. In some the quantity of livestock supplied is taken as an exogenous variable (e.g., [1, p. 797; 6, p. 169]). In others, price and feed cost are omitted, and the quantity supplied is expressed as a function of last period's inventory (e.g., [5, pp. 86–87; 6, p. 173]). In the few instances where estimates of supply functions (usually linear) for livestock are presented, with price and feed cost included as explanatory variables, it is often observed that current price and feed cost coefficients appear to have the "wrong" signs.[1]

In order to explain these effects, an approach similar to that of Reutlinger [8][2] is used to develop a simple econometric model by which the interdependence between livestock supply and inventories is clarified. The model is then applied, using the method of three-stage least-squares, to provide estimates of Canadian livestock supply functions and stock formation functions[3] for four livestock categories: cattle, calves, sheep and lambs, and pigs. The empirical results are consistent with the theoretical model. A comparison of actual and predicted values shows that the estimated functions are successful in explaining a large percentage of the observed variation in inventories and slaughter. In the final section of this paper the sensitivity of meat production to price and feed cost changes is examined.

## Implications of the Trade between Canada and the U. S.

Because of the physical problem of transporting livestock over long distances, almost all of Canada's trade in livestock is with the U. S. As a result of the proximity and the relatively low tariffs of the two countries, livestock prices in Canada are closely related to U. S. prices. Since the U. S. is a market about 10 times larger than Canada, the U. S. is the dominant partner in this relationship.[4] If, temporarily, the interaction of the Canadian demand and supply for livestock leads to a Canadian price that is significantly different from the U. S. price, arbitrage opportunities will give rise to exports or imports, as a result of which livestock prices (adjusted for exchange rate differences) in the two countries will not differ by more than the sum of the tariffs and transportation costs. In practice, even these differences disappear when prices are averaged over long periods of time.

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[1] Reutlinger [8, p. 909], for example, noted that "most agricultural economists who have tried their hands at estimating beef-supply functions have observed zero or negative elasticities of beef output with respect to beef price (and similarly, zero or positive elasticity of beef output with respect to feed price)." Similar results can be found in Langemeier and Thompson's [6, p. 173] estimate of the supply of non-fed beef, and Hayenga and Hacklander's [2, p. 543] estimate of the monthly supply equation for hogs in the U. S.

[2] Reutlinger suggests, and presents supporting empirical evidence, that this is due to two reasons. First, cows and heifers have a dual function, in that they can be slaughtered for consumption or retained to build up inventories. Second, there is aggregation error because the components of beef supply (steers, cows, and heifers) are not examined separately.

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[3] This is, I believe, the first comprehensive study of supply and inventories in the Canadian livestock sector. In the case of cattle only, estimates of inspected slaughter and inventories were recently made by Kulshreshtha and Wilson [5]. Regional estimates of the supply of cattle and hogs can be found in Kerr [4].

[4] A study of the relationship between U. S. and Canadian livestock prices can be found in Tryfos [11].

There are two implications for this study. First, since Canadian livestock prices are not the prices at which domestic demand and supply are equalized, but are determined by U. S. prices, they may be treated as predetermined variables, and separate estimates of demand and supply may be made.[5] Second, an appropriate measure of the quantity of livestock supplied is not the number of animals slaughtered, as in U. S. studies, but total slaughter plus exports; it should be noted, however, that since exports of pigs and lambs are small in relation to domestic production, the addition of exports to slaughter will be of consequence only in the case of cattle and calves.

## A Model of Livestock Supply and Inventories

At any point in time, a quantity of livestock becomes available for three uses: for slaughter in order to meet current domestic demand, for export in order to meet foreign demand, and for replenishing or increasing inventories of livestock in order to meet future demand for meat. The aggregate available quantity in a period of time shorter than the production period for the particular type of livestock considered cannot obviously vary in response to current prices and feed costs. This quantity of livestock available during period $t$, $A_t$, can be written approximately as a linear function of inventories at the beginning of the period $(I_{t-1})$[6]

$$(1) \qquad A_t = a_0 + a_1 I_{t-1}$$

where $a_1 > 0$. A part of the available quantity will be used to augment livestock inventories, while the remaining part will be used for slaughter and exports.

It is reasonable to assume that the principal determinants of "desired" livestock inventories $(I^*)$ are the expected live animal price $(P^*)$ and the expected cost of feed $(C^*)$. This relationship may be approximated by a linear function of the form

$$I^*_t = b_0 + b_1 P^*_t + b_2 C^*_t.$$

If it is assumed that—other things being equal—more will be held in anticipation of higher expected prices or lower expected costs, then $b_1 > 0$ and $b_2 < 0$.

Very little is known about the way expectations are formed. An assumption often considered adequate is that current price $(P)$ and feed cost $(C)$ may be used as proxies for expected price and cost,[7] especially when the time period implied in the subscript $t$ is relatively long. Thus, the following may be written:

$$(2) \qquad I^*_t = b_0 + b_1 P_t + b_2 C_t.$$

The relationship between actual inventory $(I)$ and desired inventory will be written as

$$(3) \qquad I_t - I_{t-1} = c(I^*_t - I_{t-1})$$

where $0 < c \leqq 1$, indicating a "partial adjustment" of actual inventory to deviations of desired inventory from the actual level at the beginning of the period (e.g., [3, p. 300]). Substitution of (2) in (3) results in

$$(4) \qquad I_t = cb_0 + cb_1 P_t + cb_2 C_t + (1 - c) I_{t-1}.$$

Total supply (slaughter plus exports) will be written as a function of the difference between the quantity of livestock available during the period $(A_t)$ and of inventory change, as follows:

$$(5) \qquad S_t = A_t - d(I_t - I_{t-1})$$

where $d$ is a positive number that is expected to be close to 1.[8]

If (1) is substituted in (5), the result is

$$(6) \qquad S_t = a_0 + (a_1 + d) I_{t-1} - dI_t.$$

Thus, the model calls for the simultaneous estimation of the following system of equations:

$$(7) \qquad I_t = \alpha_{10} + \alpha_{11} P_t + \alpha_{12} C_t + \alpha_{13} I_{t-1} + u_{1t}$$

$$(8) \qquad S_t = \alpha_{20} + \alpha_{23} I_{t-1} + \alpha_{24} I_t + u_{2t}$$

where $u_{1t}$ and $u_{2t}$ are error terms, and the expected signs of the parameters are: $\alpha_{11} > 0$, $\alpha_{12} < 0$, $0 < \alpha_{13} < 1$, $\alpha_{23} > 0$, and $\alpha_{24} < 0$. $I_t$ and $S$ are the endogenous variables; $P_t$, $C_t$, and $I_{t-1}$ are the predetermined variables.

Depending on whether the error terms of (7) and (8) are uncorrelated or not, two-stage or

[5] Demand functions for beef, veal, lamb, and pork in Canada were estimated by Tryfos and Tryphonopoulos [12], using retail meat prices as predetermined variables.

[6] The subscript $t$ denotes inventories at the end of period $t$; for all other variables, the subscript denotes averages or totals during period $t$.

[7] Also considered were various models of "adaptive expectations" (see, for example, [3]), but their performance was in general considered inferior to that of the simple model presented here.

[8] If the available quantity $(A_t)$ were known, equation (5) would be written as the identity: $S_t = A_t - (I_t - I_{t-1})$. $A_t$, however, must be estimated. It would have been very awkward to impose the restriction that the coefficient of $I_t$ be equal to one in equation (6); a convenient approach is to introduce it in (5) and to estimate it along with the other coefficients.

three-stage least-squares (2SLS or 3SLS) are appropriate methods for estimating the parameters of these equations.[9]

### Estimates of Livestock Supply and Stock Formation Equations in Canada

Equations (7) and (8) are applied to estimate Canadian livestock supply and stock formation functions for four categories of livestock: cattle, calves, sheep and lambs, and pigs.

For the first three livestock categories, annual data for the period 1951 to 1970 were used, and the estimation results are as follows:[10]

*Cattle:*

$$(9)\quad IB_t = \underset{}{1207.5} + \underset{(0.11)}{0.254PB_t} - \underset{(-0.98)}{0.605CF_t} + \underset{(13.71)}{0.863IB_{t-1}},\ U = 0.017$$

$$(10)\quad SB_t = 1076.5 + \underset{(3.71)}{1.833IB_{t-1}} - \underset{(-2.47)}{1.344IB_t},\ U = 0.023$$

*Calves:*

$$(11)\quad IV_t = 1571.8 + \underset{(3.13)}{3.088PV_t} - \underset{(-3.82)}{1.182CF_t} + \underset{(13.90)}{0.745IV_{t-1}},\ U = 0.036$$

$$(12)\quad SV_t = 459.61 + \underset{(3.97)}{1.372IV_{t-1}} + \underset{(2.10)}{0.238IM_{t-1}} - \underset{(-3.43)}{1.348IV_t},\ U = 0.036$$

*Sheep and Lambs:*

$$(13)\quad IL_t = -97.340 + \underset{(4.26)}{2.839PL_t} - \underset{(-2.41)}{0.355CF_t} + \underset{(17.53)}{1.122IL_{t-1}},\ U = 0.015$$

$$(14)\quad SL_t = -20.344 + \underset{(8.01)}{1.703IL_{t-1}} - \underset{(-4.87)}{0.998IL_t},\ U = 0.027$$

The variables are defined as follows:

*Cattle:*

- $IB$ = Beef cattle, number on farms at December 1; thousand head [10]. (Equals number of beef cows, beef heifers, and steers).
- $SB$ = Cattle, total slaughter plus exports; thousand head [10].
- $PB$ = Cattle, weighted average price at public stockyards, dollars per 100 lbs. [10], deflated.

*Calves:*

- $IV$ = Calves, number on farms at December 1; thousand head [10].
- $IM$ = Dairy cattle, number on farms at December 1; thousand head [10].
- $SV$ = Calves, total slaughter plus exports; thousand head [10].
- $PV$ = Calves, weighted average prices at public stockyards, dollars per 100 lbs. [10], deflated.

*Sheep and Lambs:*

- $IL$ = Sheep and lambs, number on farms at December 1; thousand head [10].
- $SL$ = Sheep and lambs, total slaughter plus exports; thousand head [10].
- $PL$ = Lambs, average price at Toronto of "good" lambs, dollars per 100 lbs. [10], deflated.
- $CF$ = Index of livestock feed prices, 1935–39 = 100 [9], deflated.

The index (1935–39 = 100) of prices for commodities and services used by farmers [9] was used as the deflator of livestock prices and feed costs. An additional explanatory variable—the number of dairy cattle on farms at the beginning of the year—was included in the supply function for calves in view of the dependence of calf supply on the dairy sector.

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[9] Incidentally, it is clear that the following expression for livestock supply is implied if (4) is substituted in (6):

$$(6.1)\quad S_t = (a_0 - dcb_0) + (a_1 + dc)I_{t-1} - (dcb_1)P_t - (dcb_2)C_t.$$

If the model is correct, the coefficient of price should be negative and the coefficient of feed cost positive—a result that explains some observed "inconsistent" price and cost effects. Supply functions in the form of equation (6.1) are basically used, for example, in [2, 6, and 7].

[10] The numbers in parentheses are "$t$-values." $U$ is Theil's inequality statistic (presented here as a rough measure of goodness-of-fit), defined as

$$U = \sqrt{\Sigma(P_t - A_t)^2} / (\sqrt{\Sigma P_t^2} + \sqrt{\Sigma A_t^2})$$

where $A$ are the actual values, $P$ the values estimated from the equation. The value of this statistic is in the range 0, 1. When the fit is perfect, $U = 0$; $U = 1$ indicates a zero or negative proportionality between actual and estimated values. Estimated values are calculated using the actual values of the predetermined variables only.

It was not possible to estimate all equations simultaneously because of computer limitations. Instead, the equations were estimated in three groups. Equations (9) to (12) were simultaneously estimated by 3SLS because of the correlation among the cattle and calves equations.[11] A second application of 3SLS yielded simultaneous estimates of the parameters of equations (13) and (14).

Estimates of the parameters of these equations have signs consistent with the model developed earlier. All price coefficients in the stock formation equations ($\hat{\alpha}_{11}$) are positive; all feed cost coefficients in these equations ($\hat{\alpha}_{12}$) are negative. These coefficients are clearly significant in all equations except (9)—a result which may well be due, as Reutlinger [8] suggests, to the aggregation of the components of beef supply and inventories (steers, cows, and heifers). All current inventory coefficients in the supply equations ($\hat{\alpha}_{24}$) are negative and have a value close to one in all equations; all lagged inventory coefficients in these equations ($\hat{\alpha}_{23}$) are positive. All lagged inventory coefficients in the stock formation equations ($\hat{\alpha}_{13}$) are positive, as expected, and less than unity for cattle and calves; the coefficient is, however, greater than one—1.87 standard deviations away from one—in equation (13).

In relation to cattle, calves, or lambs, the period of time appropriate to examine decisions concerning slaughter or stock build-up of pigs is much shorter. Normally these decisions are made twice a year. Equations (7) and (8) in the case of pigs were estimated by 3SLS using semiannual data for the period 1955 to 1970 (32 sets of observations) with the following results:

*Pigs (Semiannual Data)*:

$$(15) \quad IP_t^0 = \underset{}{-616.31} + \underset{(3.65)}{20.434PP_t^0} - \underset{(-3.71)}{2.576CF_t^0} + \underset{(8.68)}{1.113IP_{t-1}^0}, \; U = 0.025$$

$$(16) \quad SP_t^0 = -676.66 - \underset{(-1.75)}{0.198IP_t^0} + \underset{(7.66)}{0.916IP_{t-1}^0}, \; U = 0.022.$$

The variables[12] are defined as follows:

$IP^c$ = Pigs, number on farms at June 1 and December 1; thousand head [10].

$SP^c$ = Pigs, inspected slaughter, January to June and July to December, thousand head [10].

$PP^0$ = Pigs, average of monthly prices at Toronto, January to June and July to December, dollars per 100 lbs., Grade A hogs, dressed [10], deflated.

$CF^0$ = Average of monthly values of the index of livestock feed prices, January to June and July to December, 1935–39 = 100 [9], deflated.

These estimates are also consistent with the theoretical model. All coefficients have the expected signs. On the other hand, the coefficients of $IP_{t-1}^0$ in (15) is greater than one (although less than one standard deviation from one), and the coefficient of $IP_t^0$ in (16) is not close to one, as was expected; it is unlikely that the latter value can be attributed to chance variation.

With this one exception, therefore, it can be claimed that the empirical evidence supports the model developed earlier. Since the model's ability to approximate the time paths of the

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11 The correlation matrix of the error terms of equations (9) to (12) is estimated as follows:

| | IB | SB | IV | SV |
|---|---|---|---|---|
| IB | 1.00 | .49 | .72 | .18 |
| SB | | 1.00 | —.06 | —.44 |
| IV | | | 1.00 | .68 |
| SV | | | | 1.00 |

Since this matrix is obviously not the identity matrix, 3SLS is a more efficient method of estimation than 2SLS.

12 Inspected slaughter was used as a measure of the quantity supplied because total slaughter is not available on a monthly basis (from which semiannual data were constructed). Although monthly data on exports of pigs are available, these exports are very small in relation to the missing difference between total and inspected slaughter; it was judged that very little refinement would be gained by adding exports to inspected slaughter. The index of prices of commodities and services used by farmers (1935–1939 = 100) was again used to deflate prices and feed cost.

It should be pointed out that total ($STP$) and inspected ($SIP$) slaughter of pigs are closely related variables. With annual data for the period 1951–1970, the relationship can be estimated as follows:

$$STP_t - 0.383STP_{t-1} = 1120.36 + \underset{(39.18)}{1.077}(SIP_t - 0.383SIP_{t-1})$$

$$n = 20 \qquad d = 1.33 \qquad R^2(\text{Adj.}) = 0.99$$

where an adjustment was made for serial correlation. Thus, for forecasting purposes the above equation, modified for semiannual observations, can be used to predict total slaughter from inspected slaughter relatively accurately.

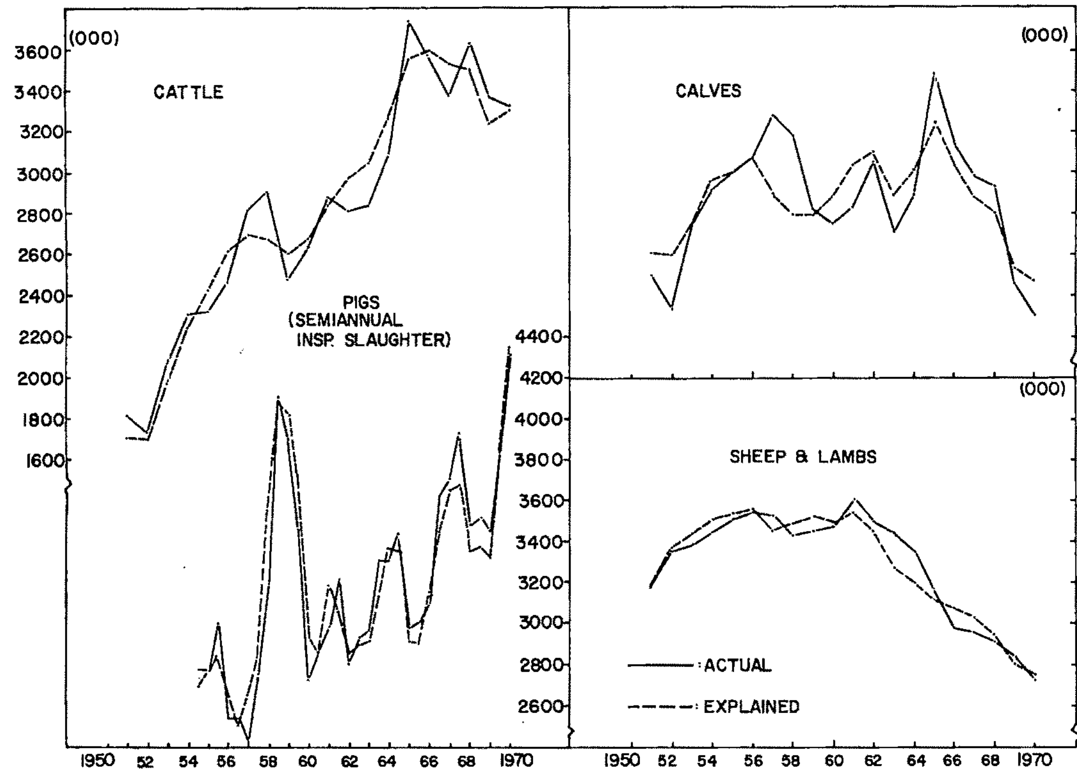


Figure 1. Livestock supply, Canada

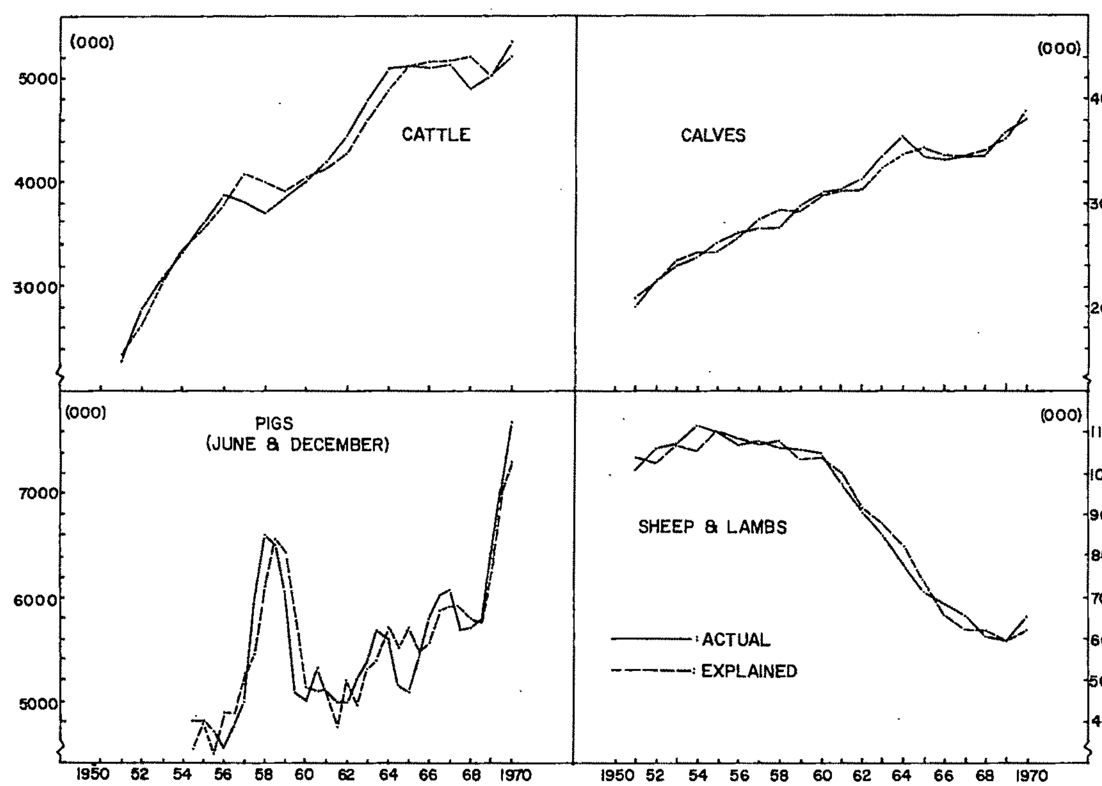


Figure 2. Livestock on farms, December 1, Canada

dependent variables is important in assessing its validity, actual and explained values of livestock supply and inventories are compared in Figures 1 and 2. Explained livestock supply is calculated from equations (10), (12), (14), and (16); explained inventories are calculated from equations (9), (11), (13), and (15).

These estimates are also used to compute the point price and feed cost elasticities of inventories and supply, shown in Table 1. In all cases, the estimated elasticities are low. Listed in order of increasing price elasticity or decreasing feed cost elasticity of inventories are: cattle, calves, sheep, pigs. The order of livestock categories according to the price elasticity of supply is slightly different: cattle, calves, pigs, sheep; the order, according to the feed cost elasticity of supply, is: pigs, cattle, sheep, calves.

## Domestic Supply of Meat

The supply of meat can be viewed as determined in two stages. In the first stage, the number of animals to be slaughtered (or exported) is determined, after demand for inventory change is satisfied; in the second stage, the *weight* of the slaughtered animals is determined. The first stage was examined in the previous section; the effect of current prices and feed cost on the quantity of meat supplied will be the subject of this section.

Feeding of livestock will be profitable when live animal prices are high or the cost of feed low. Thus, meat production ($M$) will be expressed as a linear function of current price, feed cost, and number of animals slaughtered ($ST$):

Table 1. Price and feed cost elasticities

| Quantity | Elasticities at Point of Means: Live Animal Price | Feed Cost |
|---|---|---|
| (A) Inventories of: | | |
| Cattle | 0.004 | −0.012 |
| Calves | 0.091 | −0.033 |
| Sheep and Lambs | 0.297 | −0.033 |
| Pigs[a] | 0.388 | −0.037 |
| (B) Supply of: | | |
| Cattle | −0.009 | 0.024 |
| Calves | −0.300 | 0.109 |
| Sheep and Lambs | −0.416 | 0.046 |
| Pigs[a] | −0.133 | 0.013 |

[a] Calculated from semiannual data.

(16) $MB_t$: $PB_t, CF_t, STB_t$

(17) $MV_t$: $PV_t, CF_t, STV_t$

(18) $MP_t$: $PP_t, CF_t, STP_t$

(19) $ML_t$: $PL_t, CF_t, STL_t$

where $MB$, $MV$, $ML$, and $MP$ are, respectively, the production of beef, veal, mutton and lamb, and pork, on a cold dressed basis, in million pounds [10]; $STB$, $STV$, $STL$, and $STP$ are, respectively, the total number slaughtered of cattle, calves, sheep and lambs, and pigs, in thousands [10]; the deflated live animal prices ($PB$, $PV$, $PL$, $PP$) and the deflated feed cost index ($CF$) were defined earlier.

Annual data for the period 1951 to 1970 were used to estimate the parameters of equations (16) to (19), and the results are shown in Table 2. Each equation was estimated independently by OLS.[13]

All price coefficients are positive, and all feed cost coefficients are negative. This result is consistent with previous special studies of the beef sector (e.g. [6, 5]) and clearly indicates the form of producers' response in the short run. It goes without saying that the number of animals slaughtered is the single most important explanatory variable of meat production, as is obvious from the results shown in Table 2.

## Conclusion

It has long been recognized that short-run livestock supply is related to prices and feed costs in previous periods, rather than to current prices and costs. The explanation is, of course, that a relatively long production period elapses before livestock can be brought to the market. A rise in price, for example, cannot be accompanied by an immediate increase in supply. This argument provides a justification for omitting current price and feed costs in supply equations but does not help explain significant negative price coefficients or positive feed cost coefficients.

It is also recognized that current livestock inventories will increase when favorable prices and feed costs are expected. But for this inventory change to occur, a part of the current livestock supply which would otherwise have

[13] The three equations defining, for each livestock category, inventories, supply, and meat production, respectively, form a block recursive system of equations; *OLS* is the appropriate estimation method for the meat production equation, which is the only equation in the second of the two blocks.

Table 2. Meat production functions, Canada[a]

| Dependent Variable: Production of: | Explanatory Variables: Live Animal Price | Livestock Feed Price Index | Total Slaughter | Constant | Adj. $R^2$ | $d$ | Equation Number |
|---|---|---|---|---|---|---|---|
| Beef | 2.400 | −4.430 | 0.566 | 72.470 | 0.99 | 1.15 | (16) |
| | (6.70) | (−5.69) | (38.76) | (0.72) | | | |
| Veal | 0.084 | −0.646 | 0.120 | 39.925 | 0.74 | 0.40 | (17) |
| | (0.40) | (−2.12) | (4.85) | (1.37) | | | |
| Pork | 0.550 | −0.210 | 0.138 | −107.410 | 0.99 | 1.17 | (18) |
| | (2.17) | (−0.59) | (38.42) | (−1.97) | | | |
| Lamb | 0.208 | −0.013 | 0.043 | −0.412 | 0.99 | 1.38 | (19) |
| | (2.23) | (−0.75) | (40.65) | (−0.60) | | | |

[a] "$t$-values" are shown in parentheses. $R^2$ is adjusted for degrees of freedom. $d$ is the Durbin-Watson statistic. Estimates based on annual data, 1951–1970.

been slaughtered (or exported) must be withheld from current consumption. If current prices and costs serve as signals for expected prices and costs, a rise in current price is likely to bring about an increase in current inventories and indirectly a *reduction* in the quantity that would otherwise be supplied. Similarly, a rise in feed cost will result in a decrease of current inventories and indirectly in an *increase* of the quantity that would otherwise be supplied.

Thus a case can be made that current inventory *should* appear as an explanatory variable in short-run supply functions together with lagged inventory; the coefficient of current inventory can be expected to be negative. Alternatively, current prices and costs may replace current inventory in the supply functions; the expected sign of current price is negative and of current feed cost positive.

An econometric model embodying these considerations was constructed and applied to provide estimates of the Canadian livestock supply and inventory functions. The empirical results were on the whole consistent with the model, and the estimated functions provided a good fit to the actual time series of supply and inventories.

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# Programming for Agricultural Development: The Case of Egypt*

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**A multiregional linear programming model incorporating the agronomic and institutional characteristics of Egyptian agriculture is constructed. Substantial gains would arise from crop reallocation between regions based on comparative advantage. The programmed gains would not require large additional investments or technical improvements.**

***Key words:*** **programming; Egyptian agriculture; comparative advantage.**

THERE HAS BEEN a growing interest in assessing the efficiency of farmers in allocating their resources among different production possibilities [1, 3, 8, 15, 19].[1] These cross-section production function studies revealed that only minor misallocation of resources existed. The policy implications of this condition are that decisions to develop the agricultural sector in less developed countries should focus on the increase of resources and/or the introduction of new techniques, rather than the reallocation of existing resources, given prevailing production techniques; and that planners can rely on the farmers' sense of optimization to allocate the additional resources as efficiently as they have done with existing resources. The thrust of the above conclusion is that the role of government in less developed countries should be limited only to the provision of additional resources;[2] decision-making on the level of individual farm enterprise takes care of the rest.

In contradistinction, interregional planning models, applied to India [6, 14], that formally recognized the possibilities of substitution of crops within regions and interregional shifts in land allocation among crops found that these gains were significant. These "gains from planning" include a 12.5 percent increase in production and an 11 percent increase in value of output when a reallocation of 40 percent of farmland for each crop in each region is allowed. It is emphasized that these gains in production and value of output are implied gains of a programmed plan from the given resources without additional large capital investments or technical improvements.[3]

The results of the production function studies thus appear to conflict with the results of the programming models. However, this apparent conflict can be resolved by noting that the allocative efficiency as indicated by production function studies for a sample of farms within a certain region does not preclude large gains arising from interregional shifts of production along comparative advantage lines since the *scope, nature,* and *objective* of decision-making are distinctly different in each case. To the individual farmer, the scope of decision-making is his own farm. He operates under typical uncertainty and with limited flows of information. His objective is to improve his own welfare. To the planner, on the other hand, the scope of decision-making is the entire farm sector—over thousands of farms. The objective is to develop the entire farm sector.

In this paper, a programming model of Egyptian agriculture is constructed. The objective is to estimate the magnitude of the possible gains arising from crop reallocation along lines of comparative advantage and within the context of the agronomic and institutional constraints presently existing in Egyptian agriculture. Re-

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[1] Except for Welsch [19] who dealt with the allocation of resources in Eastern Nigeria, the rest pertained to testing the allocation efficiency in Indian agriculture. However, these studies varied in terms of regions, sample size, number of crops, and number of inputs considered.

[2] The government provision of additional resources should include support of agricultural research and development and agricultural extension services.

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[3] The models applied to India were for the years 1956/57 to 1960/61; 17 regions and 16 crops (divided into five general groups) were considered. The authors further argue that greater potential gains in production and value of output might be realized if acreage changes for any one crop and region were not limited to 40 percent and if the regions considered were further subdivided in terms of climate, location, soil productivity, and other variables that relate to relative production possibilities.

sults of the study should provide a further test of the possibility of agricultural development through a more efficient allocation of existing resources.

## The Model

A matrix of 17 provinces and 25 field crops was constructed to describe the regional cropping patterns which presently exist in Egypt's farm sector. Field crops are basically divided into winter crops (10) and summer crops (15) of which eight are cotton varieties—thus emphasizing the importance of cotton to the Egyptian economy in general and to agricultural policy in particular.[4]

Compared to the Heady *et al.* model [6, 14], the present model differs in the formulation of the objective function and avoids a number of constraint misspecifications. The present authors have discussed elsewhere [16] these differences and their impact on resource allocation.[5]

Egyptian agriculture is based almost entirely on irrigation. This gives rise to two important features. The first is the identification of cultivated land as land *with* water. Land without irrigation water is simply outside cultivation activity with little or no concern to farmers. The second feature is the highly intensive nature of cultivation activity: more than one crop per year is produced on the same physical piece of land. It is therefore important to distinguish between cultivated and cropped area. Cultivated area refers to the physical land available, while cropped area refers to the average number of crops cultivated per feddan per year times the cultivated area.[6]

Data used for this model were calculated from two main sources. Cotton prices by variety and grades were obtained from direct correspondence with the Egyptian Cotton Authority; other data were obtained from "Al-Iqtisad Al-Zira'i" [12]. The nature and reporting of data dictated the formulation of the model. No data were available on physical factor inputs (labor, capital, etc.) used in the production of various crops. Only crop cost data, by province, were reported. Agricultural costs are generally of two types: (a) costs that vary depending on the crop cultivated and thus influence patterns of land cultivated; and (b) general costs that are necessary for the maintenance of farms and related facilities and thus have no influence on patterns of land cultivation [7, p. 244]. Costs reported in the present study are of type (a). With the exception of land rent, cost breakdown in the data sources referred to activities rather than to factors of production, i.e., land preparation, seeding and cultivation, irrigation, fertilization, weeding, and harvesting.

The model constructed to fit the specifications of Egyptian agriculture may be summarized in the following:

$$\text{(1)} \qquad \text{Max} \sum_{i=1}^{17} \sum_{j=1}^{25} \Pi_{ij} X_{ij}$$

subject to

$$\text{(2)} \qquad \sum_{j=1}^{9} X_{ij} = W_i$$

$$\text{(3)} \qquad \sum_{j=11}^{25} X_{ij} = S_i$$

$$\text{(4)} \qquad \sum_{i=1}^{17} X_{ij} = Z_j$$

$$\text{(5)} \qquad \sum_{j=11}^{18} X_{ij} \leqslant 0.333\, Y_i$$

$$\text{(6)} \qquad X_{ij} \geqslant b_j Y_{ij} \qquad j \epsilon J = \{1,7,20\}$$

$$\text{(7)} \qquad X_{i,25} = Y_{i,25}$$

$$\text{(8)} \qquad \sum_{j=1}^{25} \Pi_{ij} X_{ij} \geqslant I_i$$

$$\text{(9)} \qquad X_{ij} \geqslant 0$$

$$B = [b_1\, b_7\, b_{20}]$$

$$i = 1, \ldots, 17$$

$$j = 1, \ldots, 25$$

[4] Competition between crops is seasonally constrained; none of the crops is cultivated more than once during a single season.

[5] Three major differences exist between the present model and the Heady *et al.* model. First, in the formulation of the objective function, gross revenue maximization was utilized in the Heady *et al.* model versus the net revenue maximization in this paper. Substantial differences in cropping plans do result between two models with identical constraints but differing in objective function specification [16]. Second, agronomic considerations were overlooked in the Heady *et al.* model. Third, the application of comparative advantage was decidedly dampened by the upper-lower limits on crop cultivation in [6, 14]; it is given a full role in this paper by the crop-area constraint.

[6] Cultivated area, average 1965–66, was 5.974 million feddans and the cropped area 10.487 million feddans, i.e., an average of 1.75 crops per feddan per year. 1 acre = 1.04 feddans.

where

$i$ = index of provinces,
$j$ = index of crops,
$\Pi_{ij}$ = net revenue per feddan (= .96 acre) of crop $j$ in province $i$,
$X_{ij}$ = acreage to be assigned to crop $j$ in province $i$ by the solution,
$W_i = \overline{W}_i - Y_{i,10}$ total winter *cropped* area in province $i$ reduced by the area of berseem cultivation,
$S_i$ = summer *cropped* area in province $i$,
$Y_i$ = total cultivated area in province $i$,
$Z_j$ = aggregate acreage of crop $j$,
$I_i$ = total net revenue per province,
$b_j$ = a vector of minimum staple crop requirement,
$Y_{ij}$ = actual acreage of crop $j$ in province $i$,

and

$Y_{i,25}$ = actual acreage of sugar cane in province $i$.

### The objective function

The objective function is to maximize the total net revenue in the agricultural sector—equation (1). Net revenue is defined as the difference between gross revenue and type (a) costs. Average gross revenue per feddan for every crop in each province was derived by multiplying the average government prices (1965–66) by the average yield per feddan.[7]

### The constraints

The constraints follow the crop-rotation system in Egyptian agriculture, are in line with producing nonmarketed staple crops in traditional agriculture, and insure that the solution of the model does not reduce the resultant income of any province below the present level. The constraints may thus be grouped into area, crop, and income constraints.

**Area constraints.**—Intensive year-round cultivation is comprised of two seasons, winter and summer. Alternate parts of the cultivable land remain fallow in each season. In the present paper discussion follows this alternate crop pattern.

1. *Winter:* The winter crops comprise wheat, barley, flax, chick-peas, lupins, fenugreek, broad-beans, onions, lentils, and berseem (a variety of clover). The winter cropped area was reduced by the present level of berseem cultivation—equation (2)—on the grounds that (i) berseem acts as an organic fertilizer closely tied to cotton cultivation with a monetary value which is difficult to assess;[8] (ii) it is an important animal feed, and no data on cost accounting of animal husbandry in Egypt are available; (iii) it can be harvested from a single cultivation several times during the season, and no data are available on its harvesting frequency for various provinces; (iv) its costs of production are unavailable. It was, therefore, necessary to exclude berseem cultivation from the winter cropped area in every province, and thus it was not included in the solution, which insures its present level of cultivation in every province.

2. *Summer:* Summer crops comprise eight cotton varieties, rice, two maize varieties, millet, peanuts, sesame, and sugar cane—equation (3).

**Crop constraints.**—Application of comparative advantage as a guide to province specialization must not violate agronomic and institutional considerations. Important among these are the crop-rotation system, government regulations, consumption of staple crops on the farm, and location of sugar mills.

1. *Crop-Area:* Instead of placing upper- and lower-limits to variation of the present acreage of each crop in every province as in [6, 14], which would restrict the application of comparative advantage, it is stipulated here that the *aggregate* area presently cultivated of any crop should at least be maintained, although allocated differently between provinces—equation (4). The summary matrix of present cultivation of field crops shows a number of empty cells exist, i.e., each province produces *some* but *not all* crops. The solution of the model will thus be derived from the non-empty cells

[7] It was found that some cotton varieties and maize nili appear with *negative* net revenue in a few provinces. Background calculations reveal that for cotton a fall in land yields and an increase in some activities' costs (especially pest control) were responsible for negative net revenue; while for maize nili it was the low yields in the north (provinces 1–9), not compensated by cost differentials, that caused negative net revenue. Farmers' rationality in producing at negative net revenue should neither be assessed solely in the short run nor on economic factors alone. Maize is the farmers principal staple crop; cotton is Egypt's prime cash crop with a long tradition of fluctuations both in yields and in prices.

[8] Berseem cultivation precedes cotton and at least covers the same area; its effect is to halt the decline in land's fertility resulting from cotton cultivation.

only. Consequently, no province in the solution would be required to produce a crop that it did not produce before.

2. *Cotton:* In accordance with the triennial rotation system, government regulations, and farmers' past performance in the absence of regulations, the area devoted to cotton should not exceed one-third of the cultivated area in any one province [5, p. 56]—equation (5).

3. *Staple-Crops:* In traditional agriculture, part of crop production is consumed directly on the farm. This fact is taken into account in the allocation of three staple crops: wheat (#1), broad-beans (#7), and maize-sifi (#20).[9]

4. *Sugar Cane:* Sugar cane cultivation is presently concentrated in three provinces: Minia, Qena, and Asswan. It is in these provinces that the sugar mills are located in order to minimize transportation costs of the bulky sugar cane inputs. If the solution stipulates that present sugar cane cultivation be substantially altered, short of constructing new sugar mills, a conflict arises between net revenue maximization and transportation cost minimization. In the absence of the necessary information to resolve that conflict, a stipulation is introduced to maintain the present allocation of sugar cane cultivation—equation (7).

**Income constraint.**—Shifts in resource allocation and alteration of cropping patterns are bound to affect regional distribution of farmers' incomes. Unlike provinces in which income rises, the farmers in provinces that experience a decrease in income would expectedly resist such changes and possibly sabotage them. For programmed regional specialization to work out, an income constraint is integrated in the model —equation (8). This constraint is to guard against the fall of province incomes below the pre-specialization levels. Thus income gains for any province must not result in income losses for any other province.

## Results of the Model

Gains shown by the solution of the model arise from increased specialization along lines of interregional comparative advantage. These gains do not require additional inputs or improved means of production. Results of the model are presented for three variables: net revenue, area allocation, and output.[10]

Table 1. **Net revenue per province, L. E. millions**

| Province | | 1965–66 Average | Computed | Percent Δ |
|---|---|---|---|---|
| Behira | (1) | 4.85 | 5.11 | 5.43 |
| Gharbieh | (2) | 5.44 | 6.27 | 15.14 |
| Kafrel Sheikh | (3) | 3.70 | 4.34 | 17.20 |
| Dakahliah | (4) | 1.27 | 2.46 | 94.25 |
| Damietta | (5) | 0.32 | .32 | 0.55 |
| Sharkiah | (6) | 10.22 | 11.70 | 14.44 |
| Ismailia | (7) | 0.61 | 0.61 | 0.0 |
| Menoufiah | (8) | 7.96 | 7.96 | 0.0 |
| Qalioubiah | (9) | 3.16 | 4.60 | 45.62 |
| Giza | (10) | 2.20 | 2.65 | 20.68 |
| Beni Suef | (11) | 5.12 | 6.20 | 20.92 |
| Fayoum | (12) | 4.86 | 5.66 | 16.26 |
| Minia | (13) | 10.21 | 10.22 | 0.07 |
| Assiut | (14) | 8.89 | 8.89 | 0.0 |
| Sohag | (15) | 6.24 | 15.39 | 146.67 |
| Qena | (16) | 6.41 | 6.41 | 0.0 |
| Asswan | (17) | 1.49 | 2.65 | 76.82 |
| Total | | 82.99 | 101.46 | 22.25 |

### Net revenue

Table 1 shows that substantial gains in net revenue could be realized from interregional shifts in production. The total net revenue gain for the entire farm sector is 22 percent. Expectedly, this gain moves in the opposite direction to changes in staple crop requirements, albeit insignificantly. Province net revenue gains varied widely. On the one hand, four provinces showed no gain (numbers 7, 8, 14, and 16); these were evidently protected by the incorporation of the income constraint. On the other hand, four provinces showed gains in excess of 45 percent, of which Sohag showed the highest gain among all provinces (147 percent).

Table 2 shows that total net revenue derived from individual crops increases substantially in 11 cases. The *negative* total net revenue previously associated with cotton Giza 45 and cotton Menoufi is transformed into large positive gains. Revenues derived from peanuts, barley, and flax are more than doubled. On the other

[9] Maize nili was not introduced as it will eventually merge with maize sifi cultivation due to the High Dam. Rice was excluded as a staple crop for two reasons: a good part of rice production is sold for cash to government agencies; and farmers' consumption of rice is somewhat responsive to price changes [5, pp. 241–243].

[10] Three alternative levels of staple-crop requirements (the B vector) were originally included. Results of the model with respect to net revenue, area allocation, and output were generally insensitive to variations in B. The results reported in the present version pertain to the intermediate level of B.

Table 2. Area allocation, net revenue, and output

| CROP / PROVINCE | WINTER CROPS 1 WHEAT | 2 BARLEY | 3 FLAX | 4 CHICK PEAS | 5 LUPINS | 6 FENU-GREEK | 7 BROAD BEANS | 8 ONIONS | 9 LENTILS | 10 CLOVER |
|---|---|---|---|---|---|---|---|---|---|---|
| BEHIRA (1) | 201,937 | | | | | | 17,830 | | | 324,372 |
| GHARBIEH (2) | 94,483 | 10,411 | | | | | 4,373 | | | 232,523 |
| KAFREL SHEIKH (3) | 106,872 | | | | | | 9,514 | | | 240,095 |
| DAKAHLIAH (4) | 151,114 | | | | | | 3,347 | | | 363,190 |
| DAMIETTA (5) | 15,897 | | | | | | 497 | | | 76,217 |
| SHARKIAH (6) | 178,690 | | 23,896 | | | | 10,348 | | | 364,983 |
| ISMAÏLĪA (7) | 16,467 | | | | | | 667 | | | 17,810 |
| MENOUFIAH (8) | 26,485 | | | | | | 73,233 | | | 181,110 |
| QALIOUBIAH (9) | 43,732 | | | | | | 1,386 | | | 94,875 |
| GIZA (10) | 8,444 | | | | | | 38,057 | | | 66,586 |
| BENI SUEF (11) | 15,391 | | | | | | 76,013 | | | 124,357 |
| FAYOUM (12) | 117,142 | | | | | | 7,113 | | | 151,590 |
| MINIA (13) | 74,157 | | | | | | 97,001 | | | 164,069 |
| ASSIUT (14) | 21,495 | 98,052 | | 5,542 | | | 8,624 | | | 85,591 |
| SOHAG (15) | 30,283 | | | | | | 51,982 | | 80,892 | 120,966 |
| QENA (16) | 105,695 | | | 2,009 | 13,323 | 45,989 | 13,215 | 22,806 | | 43,073 |
| ASSWAN (17) | 6,472 | | | | | | 1,427 | 25,647 | | 5,810 |
| TOTAL | 1,214,756 | 108,463 | 23,896 | 7,551 | 13,323 | 45,989 | 399,717 | 48,453 | 80,892 | 2,657,217 |
| Net Revenue(000'LE) | 16,930 | 2,959 | 463 | 443 | 457 | 1,301 | 11,656 | 2,346 | 3,869 | n.a |
| % Gain | -7.09% | 146.26% | 107.53% | -0.93% | 17.88% | 17.98% | 30.43% | 62.10% | 44.14% | |
| Output (000' unit) | 8,678 | 1,501 | 89 | 36 | 70 | 237 | 2,733 | 8,488 | 405 | n.a |
| % Gain | -4.55% | 57.99% | 14.03% | 0.50% | 10.14% | 8.81% | 16.80% | 4.34% | 24.38% | |

| CROP / PROVINCE | SUMMER CROPS Cotton Varieties 11 GIZA 45 | 12 MENOUFI | 13 GIZA 68 | 14 GIZA 47 | 15 GIZA 67 | 16 DANDARA | 17 ASHMOUNI | 18 GIZA 66 | 19 RICE | 20 MAIZE SIFI | 21 MAIZE NILI | 22 MILLET | 23 PEANUTS | 24 SESAME | 25 SUGAR CANE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BEHIRA (1) | | 230,397 | | | | | | | 216,674 | 103,465 | | | | | |
| GHARBIEH (2) | 143,540 | | | | | | | | 138,520 | 76,299 | | | | | |
| KAFREL SHEIKH (3) | | 143,083 | | | | | | | 201,230 | 41,348 | | | | | |
| DAKAHLIAH (4) | | 124,469 | 89,729 | | | | | | 73,228 | 38,770 | 257,943 | | | | |
| DAMIETTA (5) | 9,399 | 22,200 | | | | | | | 42,115 | 5,403 | | | | | |
| SHARKIAH (6) | | 121,914 | | 88,172 | | | | | 134,200 | 187,085 | | | | | |
| ISMAÏLĪA (7) | | 17,026 | | | | | | | 9,753 | 7,662 | | | | 4,281 | |
| MENOUFIAH (8) | | | | 97,483 | 7,187 | | | | | 163,047 | 14,927 | | | | |
| QALIOUBIAH (9) | | | | | 57,397 | | | | | 86,463 | | | | | |
| GIZA (10) | | | | | | | 55,077 | | | 42,503 | | | | 27,889 | |
| BENI SUEF (11) | | | | | | | 89,719 | | | 13,500 | | 133,910 | | | |
| FAYOUM (12) | | | | | | | 104,589 | | | 1,400 | | 100,700 | | | |
| MINIA (13) | | | | | | | 81,179 | 69,839 | | 90,473 | 64,888 | 65,729 | | | 19,122 |
| ASSIUT (14) | | | | | | | 108,031 | | | 15,569 | 151,291 | | 5,331 | | |
| SOHAG (15) | | | | | | 52,688 | 58,349 | | | 97,723 | | | 80,944 | | |
| QENA (16) | | | | | | 69,653 | | | | 13,131 | | 123,425 | | 6,703 | 62,809 |
| ASSWAN (17) | | | | | | | | | | 1,795 | 29,296 | | | | 32,144 |
| TOTAL | 152,939 | 659,089 | 89,729 | 185,655 | 64,584 | 122,341 | 496,894 | 69,839 | 815,720 | 985,646 | 518,345 | 457,806 | 86,275 | 38,873 | 114,073 |
| Net Revenue(000'LE) | 1,254 | 855 | 956 | 1,385 | 1,931 | 594 | 4,266 | 913 | 7,264 | 21,108 | 4,192 | 6,045 | 7,115 | 973 | 2,079 |
| % Gain | * | * | 56.76% | 81.78% | 26.29% | -3.75% | -9.42% | 5.04% | 14.79% | 7.49% | 97.99% | -19.48% | 221.00% | 42.78% | 0.00% |
| Output (000' unit) | 670 | 2,836 | 459 | 993 | 444 | 549 | 2,539 | 421 | 1,788 | 12,289 | 5,003 | 4,658 | 1,471 | 146 | 99,095 |
| % Gain | 24.11% | -0.78% | 9.68% | -8.44% | 5.01% | -0.36% | -1.41% | 0.67% | 0.59% | 0.99% | 27.39% | -14.94% | 144.69 | 8.04% | 0.00% |

Notation: n.a.—not available (for Clover).

*—denotes change in net revenue from negative to positive (for Cotton Giza 45 and Menoufi).

hand, total net revenue derived from five crops declined in varying degrees, the largest decline being for millet of about 20 percent.[11]

The above gains in net revenue were obtained under rather stringent constraints; the relaxation of some produces substantial increases in these gains. Five constraints were individually removed. Subsequent increases in aggregate net revenue over the above gains were: 6 percent from removal of the income constraint, 45 percent from the sugar cane constraint, 56 percent from the staple-crop constraint, 57 percent from the cotton constraint, and 178 percent from the crop-area constraint. In the last four cases, the income constraint was automatically satisfied. These latter results measure the degree of constraint stringency; the crop-area constraint evidently being the most restrictive. Yet it is precisely this constraint which, when maintained, highlights the contribution of a programmed reorganization of the farm sector.

### Area allocation

The matrix solution for the area allocation is presented in Table 2 and is found to be substantially more sparse than the pre-specialization matrix. The resulting degree of specialization which is greater than might be expected can be explained by the fact that no minimum restraints on province output, other than staple crops, were introduced in the model.

As a measure of the degree of specialization, when the number of non-empty cells in Table 2 is contrasted with the pre-specialization matrix, a 49 percent reduction is found in the number of non-empty cells. For winter crops, the number of non-empty cells in the solution falls by 56 percent and for summer crops by 42 percent with cotton showing the smallest decrease (35 percent). Production of some crops becomes totally concentrated in one or two provinces: barley, flax, chick-peas, lupins, fenugreek, onions, lentils, peanuts, and sesame. Not surprisingly, each of these crops occupies a small total area—with the exception of barley, none exceeds 100 thousand feddans. Therefore a more profitable cropping pattern would require those small-area high-profit crops to be concentrated in the provinces most suited in their production.

The number of crops per province is substantially reduced following a more profitable pattern of crop production. The percentage reduction ranges from 25 percent for Damietta (#5) to 69 percent for Qaliobiah (#9). This, however, should not be interpreted to mean that the smaller the number of crops produced in a province the higher the gain in that province's income.

### Production

Table 2 shows that the relative changes in crop output are generally less than the corresponding relative changes in net revenue. Although no clear correlation exists between output gains and revenue gains, the five crops—barley, lentils, cotton Giza 45, maize nili, and peanuts —which show the largest relative gains in crop output, over 20 percent, also show substantial relative gains in net revenue.

Table 3 is a summary of the resulting gains in real output and the corresponding gains in net revenue by commodity groups. Again, the former are systematically below the latter. Arranging crops in homogeneous groups, output gains appear positive throughout. Of special interest in this regard is the food grains group for its impact on the level of food consumption and the cotton group for its impact on the country's foreign-exchange earnings. For food grains, the fall in output of wheat and millet would be compensated by the rise in output of the other grains, particularly barley and maize nili. For the cotton group, the fall in output of

**Table 3. Resulting gains in net revenue and real output by commodity groups**

| Commodity or Group | Percentage Changes: Net Revenue | Percentage Changes: Real Output |
|---|---|---|
| Food Crops | | |
| Grains | 6.34 | 1.81 |
| Legumes | 30.74 | 16.76 |
| Export Crops | | |
| Cotton | 56.10 | 0.47 |
| Rice | 14.79 | 0.59 |
| Onion | 62.10 | 4.35 |
| Peanuts | 221.00 | 144.62 |

[11] With the exception of chick-peas, those crops show corresponding declines in production arising from a different distribution of land cultivation although the total area for each has remained the same. As Table 2 shows, not every decline in crop output was accompanied by a corresponding decline in net revenue. For example, cotton Menoufi and cotton Giza 47 show a decline in output, but substantial *gains* in net revenue can now be derived from their programmed cultivation plans. It should be recalled that the model was formulated to maximize total net revenue and not output, with no explicit constraints on the level of output that would be produced of any crop.

long and medium staple varieties would be reversed by the rise in output of extra-long staple varieties of Giza 45 and Giza 68. This is crucial to the country's foreign-exchange earning capacity since cotton exports are concentrated in the extra-long and long staple varieties, while domestic consumption is concentrated in medium staple varieties [13, several issues].

Change in province *product* mix would be expected to require changes in province *input* mix which would alter costs of production. Allowing for interprovince compensatory mobility (at the margin) of resources other than land may limit the extent to which costs of production would increase as a result of specialization. In fact, it was found that for most provinces cost expenditures on each activity as well as *total* cost of production remained nearly the same for individual provinces after specialization. These small variations in province costs generally cancelled out, with the consequence that *aggregate* production costs *for the sector as a whole* showed a minute decline.[12] The implication is that province resources, although mobile except for land, are allocated differently among crops such that total province resource use remains nearly the same.

The above costs of production do not include additional transportation costs which may be required by increased specialization. In the absence of data to estimate such additional costs, a number of points should be noted that may limit the scope of the transportation problem. First, the model stipulates that minimum production of the three staple crops (wheat, broadbeans, and maize) be met in each province, which would limit additional demands on the transportation network. Significantly all three are major crops in terms of total area cultivated and/or total output. Second, with the exception of onion, none of the other major crops—sugar cane, cotton, rice, and millet—showed substantial variation in land reallocation and consequently in resulting output. Finally, the crops that do show the largest province changes—barley, flax, lupins, fenugreek, peanuts, and sesame—are generally minor crops in terms of total area and output; hence their impact on the transportation network is likely to be insignificant.

## Conclusion

Numerous studies showed that farmers in less developed countries respond to economic incentives [2, 4, 9, 10, 11, 17, 18]. The question is why has regional specialization, as called for by the solution of the model, not already been achieved through the market mechanism? It was emphasized earlier that farmers operate under uncertainty with respect to prices and yields The result is that the farmer, on the one hand, hedges against these uncertainties by diversifying his production, and on the other, is reluctant to divert substantially from an established pattern of production. Subsistence farming and a measure of self-sufficiency, particularly on the village level, follow from such patterns of behavior. The fact that opportunities for gain do exist beyond the confines of the village does not always mean that the farmer will reach out for them and accordingly adjust his cultivation pattern.

Unlike the farmer's fragmented view, the planner's scope of decision-making is the entire agricultural sector. He operates under less uncertainty and with substantial flows of information. The gains indicated are therefore "gains from planning," which could be achieved by offering price and/or quantity crop insurance to the farmers instead of dictating what they should grow.

A number of qualifications regarding the model could be made. First, there are problems associated with implementing the results of programming models of this type. The province specialization results of this model should not be construed as once and for all changes in the agricultural sector; rather, they must be viewed in a dynamic context. While the results of such a model may be implemented for one year through economic incentives and/or administrative directives, such policy measures must continuously change in line with changing conditions which would affect regional specialization.[13] Furthermore, while this paper's policy guidelines are *ex post*—what farmers *should have done*—actual policy making is *ex ante*, based on *expected* relative prices and yields for each crop per province—what farmers *should do*.

Second, while the model reveals that substan-

[12] Available costs of production of various crops in every province were able to be divided into basic activities such as land preparation, seeding and cultivation, and irrigation. Total province expenditures on each activity in the two cropping seasons were calculated before and after specialization, and no significant differences were found for any activity.

[13] However, substantial changes in the results from year to year are unlikely unless perceptible changes in relative prices and yields suddenly occur. Over a long period of time, the accumulation of these minor annual variations may lead to significant changes in the province specialization results.

tial potential gains exist, the actual gains achieved with specialization could be much lower. This is due to various types of costs that might be incurred with implementation of the program: (a) a basic assumption of the model is constant returns to scale in the production of each crop per province,[14] and therefore, with specialization, if diminishing returns are encountered in the production of some (or all) crops, the gains indicated by the model would be reduced accordingly; (b) increased specialization would invariably put additional strains on the already overtaxed transportation system in Egypt and province specialization would require the expansion of that sector, (c) incremental costs associated with crop insurance plans as a result of increased specialization and risk, in addition to the cost of information flows between planners and farmers; (d) to the extent that after-specialization changes in the output of various crops may affect the prices farmers would receive, the solution of the model may have exaggerated the gains from such specialization.

[14] The assumption of constant returns to scale implies perfect substitutability of land within each province among various crops.

Thirdly, the model can be criticized on the ground that factors of production other than land were not *explicitly* introduced in the constraints. However, this does not mean that those factors had no influence on the interregional allocation of crops. Production factors have in fact played a major role in the present model. Conventionally, they would have entered as constraints. Due to data limitations, however, they entered the model *indirectly* through production costs in the formulation of the objective function. Implicit in the model is the assumption of fixed proportions in the production of each crop per province. Specifically, following the solution of the model, the reallocation of one feddan of "land" from crop A to crop B in province *i* is also a reallocation of the other complementary resources, especially water, from A to B in the same province. Similarly, the reassignment of crops between provinces might well require that some resources, complementary to land, are reallocated through interprovince mobility of factors. The less mobile those resources are, the lower the gains from planned specialization.

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# The Measurement of Buyer Brand Preference and Indifference Under Changing Terms of Trade

EVAN E. ANDERSON

A model first suggested by Padberg, Walker, and Kepner has been employed in this paper to evaluate the impact of changes in the retail terms of trade on the magnitude and composition of consumer brand preferences.

*Key words:* impact; terms of trade; brand preferences.

SCHOLARS AND PRACTITIONERS who are interested in the market activities of buyers and sellers have universally accepted the role of brand price, perhaps the absolute, and certainly the relative size thereof, as a primary variable in the determination of the quantity demanded and firm market share. A vast literature describes and conceptualizes the numerous impacts which brand price may have on the consumer's choice between available products and brands. This literature has considered and must consider the existence of non-price frictions in the market which modify expectations of buyer reaction to price per unit relative to expectations under conditions of complete brand indifference. The very existence of brands, even without promotions, real product quality variations, and other forms of non-price competition, permit, if not induce, the creation of brand preferences. The emergence of brand preference, even if fragile, represents a source of friction in the market place that may act to reduce the importance of price as a purchase consideration in the consumer's choice between alternative brands.

The earliest research into the existence of brand loyalties utilized the historical purchase records of families for low-priced, frequently purchased items [3]. These early inquiries were followed by attempts to associate various measures of brand preference with facets of the product, market, and buyer [4, 5, 7]. Other models of brand choice have described the selections of consumers with learning and Markovian models, and in general have continued to rely on the purchase data of consumer panels [6, 8, 9, 10, 11, 12, 13, 15].

This paper is concerned with the reaction of consumers to branding and the influence which the price and non-price activities of the firm have on consumer brand preferences in retail markets. It departs from most prior investigations of brand preference because it concentrates on the *existence and measurement* of brand preference, or indifference in final good markets and not with tracing the path of preference development; it is concerned with measuring the brand preference of an *entire market* rather than the brand preference of particular buyers who have agreed to participate in a consumer panel; and it specifically examines the occurrence of *short run* brand switching that results from *changes* in product pricing and promotional conditions.

The succeeding methodology, first suggested by Padberg, Walker, and Kepner [14], and the concomitant market experiment seek to measure the effect which changes in price and trading stamp premiums have on consumer brand preference and the distribution of industry sales between brands. Specific attention has been given to determining, at least for the product under study, whether market share changes resulting from adjustments in brand terms of trade seem to arise from a switching of brand preference buyers from one brand to another, or from a reduction in the number of brand indifferent buyers, who now view the changes in market variables as sufficient reason to prefer one brand rather than others.

## Potential States of Consumer Brand Preference

Definitions are as follows:

$M, D =$ the two brands (a manufacturer's brand and private label distributor's brand) of the specific product under study displayed by experimental stores;

$Q_M, Q_D =$ the quantity of each respective brand sold; the sample size, or total number of sale units observed, $Q_T$, is predetermined and constant; $Q_T = Q_M + Q_D$;

$Y_M, Y_D =$ the market shares of brands $M$ and

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$D$, i.e. $Y_M = (Q_M/Q_T)$ and $Y_D = (Q_D/Q_T)$;

$SS_M =$ the proportion of total product display space allotted to $M$, $(0 \leqq SS_M \leqq 1)$; the remaining fraction of product shelf space, $SS_D = (1 - SS_M)$, is assigned to brand $D$;

$\theta =$ the proportion of sales resulting from buyers *without* a brand preference, $(0 \leqq \theta \leqq 1)$;

$m =$ the proportion of sales made to brand preference buyers *who prefer* $M$ to $D$. The remaining proportion of sales made to brand preference buyers, $d = (1 - m)$, is the proportion of $(1 - \theta)$ which prefers brand $D$.

Recognizing that the market share of brand $M$ depends on the relative terms of trade, the magnitude of $SS_M$, as well as numerous non-price factors, one may posit the following possible market cases based on the existence and character of consumer brand preference.

### Case A. Complete brand indifference

This potential segment of market demand, given the conditions of sale, exhibits no preference for either brand. These buyers are completely indifferent between brands and would freely substitute, without an economic incentive, one brand for the other. In this market circumstance consumers would perceive no difference between the products or terms of trade and/or would disregard disparities which do exist.

Brand indifferent buyers make a bias-free, completely random choice between the displayed brands. Random buyers are totally casual about the outcome of their brand choice from the retail shelf and exhibit a purchasing process which is analogous to the drawing of colored balls from an urn. Hence, the expected market share of brand $M$, given a state of total brand indifference, would be equal to the proportion of the total product display area (shelf space), $SS_M$, it receives:

$$(1) \qquad E(Y_M) = SS_M.$$

Since random buyers make a very casual choice between brands at the display shelf and make no attempt to discriminate between brands, the larger the number of facings received by brand $M$, the greater the likelihood that it will be drawn in any single trial.

### Case B. Complete brand allegiance

This market condition arises where all buyers have, and exercise, a specific brand preference by making a *specific brand choice* for either brand $M$ or brand $D$. Brand preference buyers, within the self-service retail store, make a deliberate, calculated attempt to find the brand they prefer on the retail shelf. This market condition posits the existence of buyers who perceive a difference between the want-satisfying qualities of the goods and/or their terms of trade. These differences whether based on real or imagined disparities have utility implications for the buyer such that they are willing to bear the burdens associated with searching for their preferred brand. The expected market share of brand $M$, then, where *all* buyers exhibit a brand preference is equal to the proportion of the brand preference sales made to buyers preferring brand $M$, i.e.,

$$(2) \qquad E(Y_M) = m.$$

In an experimental context this result may be described as the mean proportion of sales of brand $M$ (a success) out of the total quantity of sales observed, $Q_T$. If an experiment consists of $Q_T$ total randomly observed sales, where the probability of observing the sale of the manufacturer's brand $M$, $(\phi)$, is constant from trial to trial, and where $Q_M$ is a random variable whose value for any outcome of the experiment is the total number of sales of the manufacturer's brand, then $Y_M$ and $Q_M$ have the same binomial distribution with parameters $\phi$ and $Q_T$. Hence $E(Y_M) = \phi$ and $E(Q_M) = \phi Q_T$.

The probability distribution for the random variables, $Y_M$ and $Q_M$, is given by

$$(3) \qquad P(Y_M) = P(Q_M) = \binom{Q_T}{Q_M} \phi^{Q_M}(1-\phi)^{Q_T - Q_M}.$$

### Case C. Mixture of random and brand preference buyers

The two preceding cases represent extreme assumptions about the nature of consumer brand preference. Case C is characteristic of most markets and can be represented by a model which combines the two prior cases and concedes that some customers act on definite brand preference

while others exercise no discrimination between brands and select a brand at random [14, p. 726].

The expected value of the market share of brand $M$ for Case C consists of the sum

(4) $$E(Y_M) = (1-\theta)m + \theta SS_M.$$

The variance of this binomially distributed sample proportion is

(5) $$VAR(Y_M) = \frac{1}{Q_T}[(1-\theta)m + \theta SS_M][(1-m) + \theta(m - SS_M)].$$

Equation (4) was expressed by Padberg, Walker, and Kepner as the simple linear regression equation [14, pp. 725–26],

(6) $$Y = \beta_o + \beta_1 X + \epsilon$$

where $Y = E(Y_M)$, $\beta_1 = \theta$, $X = SS_M$, $\beta_o = (1-\theta)m$, and $\epsilon$ is the disturbance term.

Equation (6) may then be used to measure, under experimental conditions, the proportion of observed sales ($m$) made to consumers who have a preference for brand $M$; the proportion of sales ($d$) stemming from buyers with a preference for brand $D$; and the proportion of observed sales ($\theta$) made to random buyers. Thus, the market share proportions, $(1-\theta)m$ and $(1-\theta)d$, correspond to the fraction of product sales made to buyers who exhibit a brand preference for brands $M$ and $D$ respectively. The variable segment of any brand's market share is determined by the amount of random buying that occurs in the market, and by the proportion of total product facings that it is accorded in retail stores. Since $\theta$ is a market parameter that affects each brand equally, the allocation of total random sales, $\theta \cdot Q_T$, between brands is determined by the retail division of shelf space, $SS_M$, $SS_D$. The expected quantity of brand $M$ demanded by random buyers is then $SS_M \cdot \theta \cdot Q_T$.[1]

## Model Specification and Estimation

Estimation of $(\beta_o, \beta_1)$ for (6) by OLS would not generally yield best linear unbiased estimates. Specifically, the distribution of the disturbance term, $\epsilon$, has a zero mean and variance [16, pp. 71–79],

(7) $$VAR(\epsilon) = \frac{1}{Q_T}[\beta_o + \beta_1 X][1 - \beta_o - \beta_1 X]$$

which is heteroscedastic and varies with $X$.

In general the minimum variance linear unbiased estimate for $\beta_o + \beta_1 X$, where random variables $Y_i$ have different variances, is an estimate using the weighted least squares estimates, $\beta'_o$ and $\beta'_1$ [16, p. 244]. It may be shown [1, pp. 109–111], however, that the OLS estimates are equivalent to the weighted estimates when *two* display space proportions are used. In this special case, the unweighted estimate $\hat{\beta}_o + \hat{\beta}_1 X$ is the minimum variance unbiased estimate. Additionally, where estimation is based on only two observations, the estimates are maximum likelihood.[2]

## Empirical Measurement of Brand Preference

Data for this research were gathered by directly observing the market behavior of consumers in a controlled retail store experiment. Eight different market treatments were randomly applied to the sale of the one pound loaf of white bread.[3] Observations were completed simultaneously in three medium size (sales volume) supermarkets in central New York.

The market setting and environmental character of the buying circumstance were continually monitored and maintained by the observer and were arranged such that the buyer was unaware of the experiment. Most sources of heterogeneity were controlled through the cooperation of retail management, while the pricing, trading stamp,

[1] The fraction of total product display area received by brand $D$ is $SS_D = (1 - SS_M)$. Hence the variable segment of demand for brand $D$ is $(1 - SS_M)\theta Q_T$.

[2] This, however, restricts the degree of freedom such that we are unable to test formally the various hypotheses about the parameters.

[3] The following market treatments describe the eight different conditions existing between brands $M$ and $D$ in this experiment: (a) $(r_1, t_1, s_1)$ = unequal prices, no extra stamps on $M$, and one-third the display space allocated to $M$; (b) $(r_1, t_2, s_1)$ = unequal prices, extra stamps attached to $M$, and one-third the display space allocated to $M$; (c) $(r_1, t_1, s_2)$ = unequal prices, no extra stamps on $M$, and two-thirds the display space allocated to $M$; (d) $(r_1, t_2, s_2)$ = unequal prices, extra stamps attached to $M$, and two-thirds the display space allocated to $M$; (e) $(r_2, t_1, s_1)$ = equal prices, no extra stamps on $M$, and one-third the display space allocated to $M$; (f) $(r_2, t_2, s_1)$ = equal prices, extra stamps attached to $M$, and one-third the display space allocated to $M$; (g) $(r_2, t_1, s_2)$ = equal prices, no extra stamps attached to $M$, and two-thirds the display space allocated to $M$; and (h) $(r_2, t_2, s_2)$ = equal prices, extra stamps attached to $M$, and two-thirds the display space allocated to $M$.

and display treatments were randomly assigned by a split-plot factorial treatment design.

### Market variables

Two market variables were used to define the treatment terms of trade.

### Retail price per unit, with levels

(i) $r_1$ = a state where the price of the manufacturer's brand $P_M$ exceeds the price of the private labeled brand, $P_D$, by a constant amount, i.e. $P_M = aP_D$, $a > 1$. In this study $a = 1.49$.

(ii) $r_2$ = a state where the per unit prices of brands $M$ and $D$ are equalized through a reduction in the price of $M$.

### Trading stamp premiums

(iii) $t_1$ = a state where no premium of additional trading stamps is attached to either brand $M$ or $D$.

(iv) $t_2$ = a state where an extra quantity of trading stamps, which cost the retail firm an amount $P_M[(1-1/a)]$ per unit of bread sold, was physically attached to each unit of brand $M$ displayed.

Four different competitive treatments were then defined from these two variables and their levels.[4] Separate regression equations of the form (4) and (6) were estimated for each of the following market treatments: I = [(i) and (iii)]; II = [(i) and (iv)]; III = [(ii) and (iii)]; and IV = [(ii) and (iv)]. The merging of these four terms of trade treatments with the display space treatments resulted in the eight treatments shown in footnote 3. Since this study is concerned with the sensitivity of brand preference parameters to changes in inter-brand terms of trade for a retail region, data were grouped across the community's three stores.[5]

It is evident from the information contained in Figure 1 and Table 1 that a substantial proportion of the observed bread sales resulted from a deliberate brand selection rather than a random choice. Approximately three-fourths of the sales made were motivated by a preference for one brand or another during relatively normal trad-

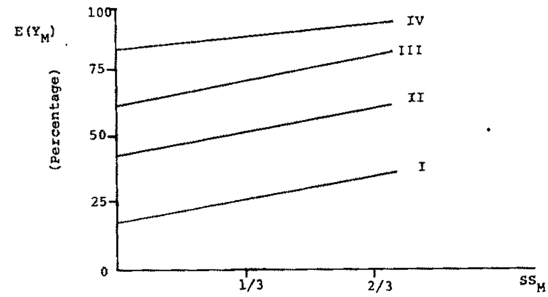


**Figure 1. Empirical estimation of brand preference parameters: equation (4)**

ing conditions.[6] However, the extraordinary promotional conditions of a price reduction and additional trading stamp coupons resulted in over 90 percent of the bread sales being based on a preferred brand choice. The extent of brand preference, $(1 - \theta)$, in the market appears to be a relatively stable phenomenon under typical (I, II, III) promotional conditions.

It is very interesting to note, however, that as the difference in the terms of trade between brands $M$ and $D$ becomes increasingly greater, a larger and larger fraction of the sales were made to buyers who perceived a difference between brands and employed that perception in brand selection. This phenomenon is most noticeable in the case of state IV, where both a price reduction *and* trading stamp premium were placed on brand $M$. One can see in Table 1 that the share of preferenced sales, $m$, made to $M$ increased to 92 percent in state IV from 26 percent in state I and that a larger fraction (75 percent to 92 percent) of total market sales is made to buyers who exhibit a brand preference in state IV, relative to state I. Large differences in brand terms of trade may provide nearly all buyers with a sufficient reason to prefer one brand rather than another. Brand indifference is a relative phenomenon and does not exist indefinitely in the same magnitude, regardless of market conditions. Certainly one could imagine many market conditions for even this product class, where no indifferent buyers would exist, i.e. $\theta = 0$.

Simultaneously, substantial adjustments have

[4] The pricing and trading stamp treatments were introduced by point of purchase materials. The extra trading stamp coupon placed on each loaf of bread was familiar to customers and was used regularly by the store. Quality of the display area was made more homogeneous by randomly rotating the position of each brand in terms of the flow of traffic.

[5] $Q_T$ = 360 observed sales at each of two display space proportions, for each price-stamp treatment.

[6] The interpretation of $\beta_0$ when $SS_M = 0$ is not entirely clear since it is impossible to have "preference based" sales when brand $M$ is unavailable. Nevertheless, the display space allocation, $SS_M = 0$ does not necessarily imply that no *potential* preference based sales existed. This state represents the situation where consumers may have a preference for brand $M$ but are unable to demonstrate their preferred choice because it is unavailable.

Table 1. Estimates of the brand preference parameters under various competitive conditions

| Competitive conditions between brands | Percentage of preference motivated sales $(1-\Theta)$ | Percentage of preference motivated sales going to consumers that prefer $M$ $m$ | Percentage of sales motivated by a brand preference for $M$ $(1-\Theta)m$ | Percentage of sales made to buyers who are completely indifferent between brands and make a brand choice at random $\Theta$ |
|---|---|---|---|---|
| I | 75.00 | 26.30 | 19.72 | 25.00 |
| II | 76.68 | 60.52 | 46.41 | 23.32 |
| III | 74.17 | 83.52 | 61.95 | 25.83 |
| IV | 91.67 | 91.70 | 84.06 | 8.33 |

been observed in the *direction* of brand preference ($m$ relative to $d$) resulting from disparities in the terms of trade between the two brands. In general one must conclude that the market for this product consists primarily of buyers who are highly sensitive to the conditions of sale between the brands. While there is a remarkable stability, over states I, II, and III, in the segment of buyers who have a brand preference and those who buy at random, the percentage of preference-motivated sales arising from consumers who prefer $M$, $m$, ranges from a low of 26 to a high of 92 percent. Conversely, the fraction of brand preference buyers, $(1-\theta)$, who prefer brand $D$, $d$, varies between 84 percent and 8 percent. Hence for states I, II, and III one may conclude that there is a substantial amount of brand switching, even though the division of preference and random based sales is relatively stable.

The empirical evidence observed here, for states I, II and III, seems to imply that the phenomenon of brand allegiance, though not its disposition, may be to some extent the result of behavioral or psychological qualities of buyers rather than marketplace phenomena. Table 1 shows that even when the conditions of sale are completely equalized between brands, state III, the percentage of preference motivated sales, $(1-\theta)$, remains at approximately 75 percent. This suggests that a substantial amount of brand loyalty may exist, even when the physical products and conditions of sale are virtually identical. Hence, it seems that the sheer act of branding, may greatly reduce the presence of indifferent buyers, i.e., all individual indifference curves for the two brands may not be linear with a slope of minus one, even if the goods differ only by name.

Direction of preferences, that is, the reasons for preferring one brand rather than another, are probably varied, dynamic between individuals, and are assuredly very complex for entire markets. On the basis of this experiment, it seems that a fairly stable fraction of the market $(1-\theta)$ exhibits a brand preference but that inter-brand terms of trade function as a weathervane for brand allegiance. Hence it may be, under typical market conditions, that most buyers naturally develop *a* favorite brand. However, the market terms of trade may determine which *specific* brand is selected as the favorite as well as the duration of this allegiance.

Comparison of the estimated brand preference parameters of this study, for bread, with those of Padberg, Walker, and Kepner [14, p. 730–731] for milk, indicates that a much higher degree of random buying exists for fluid milk than for bread. Their study of brand preferences for fluid milk within a major metropolitan area was generally conducted under market conditions similar to those of I and III in this study. When there was no variation in container type, they found that $\theta$, the fraction of sales made to random buyers, was at least 44 percent of total sales and at times as high as 60 percent of demand. This is substantially larger than the $\theta = 25$ percent found in this study (conditions I and III).

A very interesting similarity in the results of these two studies involves disposition of brand preference buyers between brands. When a price difference existed between the manufacturer's milk and the distributor's private brand milk, a maximum of 40 percent of the brand preference buyers preferred the manufacturer's brand. However when the prices of the two milk brands were equalized, the proportion of sales made to

those preferring the manufacturer's brand increased to over 80 percent. Similar kinds of brand preference adjustments were observed in this study, where *m*, the fraction of brand preference sales made to those who prefer the manufacturer's brand, *M*, increased from 26 percent to 84 percent as price differences were removed.

The higher fraction of random sales observed by Padberg *et al.* for milk relative to bread may be accounted for by the extraordinary physical standardization existing for milk. Sanitation and grading regulations governing the processing of milk may cause consumers to perceive the milk brands as being extremely homogeneous. The relative homogeneity of milk may also make it more difficult for processors and retailers to create brand differences, in the minds of consumers, through advertising and sales promotion. Bread, alternatively, may vary considerably according to freshness and texture. Given the potential for real differences, consumers appear to believe that a brand allegiance is justified or perhaps even necessary.

## Implications for Retail Management

The brand preference parameters estimated by equation (6) are of use to marketing management in at least two areas. First, this model may be used specifically to evaluate the promotional strength of various price and non-price marketing strategies available to the manufacturer and channel of distribution. For example, the data generated by this study could be employed to consider the "comparative promotional pull" of a price reduction relative to a trading stamp premium when costs of such promotions to the supermarket chain are equalized. When both treatments were applied to brand *M*, market conditions II and III, the promotional impact of a price reduction was considerably stronger than a trading stamp special having equivalent costs to retail firms. The price reduction stimulated an *additional* increase of 23 percent[7] in the proportion of brand preference buyers who prefer brand *M*, "*m*", above the increase in *m* induced by the trading stamp special. The incremental promotional power of the price reduction observed in this study raises some doubts as to the economic justification of trading stamp premiums, at least for the period studied.

A second use which retail management can make of estimated brand preference parameters concerns the exact context within which this experiment occurred. The model employed in this study varies the fraction of display space assigned to each brand. Given the various expected market shares generated by this methodology, and the per unit profit contribution of each brand, it is possible to determine the most profitable allocation of a given product display area between brands *M* and *D*. The amount of control over *product* class profits depends primarily on retail management's capacity to encourage the purchase of some brands and discourage the purchase of others through the assignment of brand display areas. The amount of leverage in determining the composition of its sales, however, depends not only on the judicious assignment of display surface, but also on the presence of random buyers.

## Conclusion

This paper has employed a brand preference measurement model, first suggested by Padberg, Walker, and Kepner, to explore the sensitivity of the phenomenon of brand preference and the direction of brand preferences as the market terms of trade vary. Several modifications were made in the experiment and analysis to overcome econometric problems associated with the original model.

A considerable amount of brand switching was observed as a result of changes in the terms of trade. However, the fraction of total demand associated with random and brand preference buyers, respectively, seems very stable for those promotional conditions generally witnessed in retail markets. Additionally, the fluidity of brand allegiance observer for those buyers tending to exhibit a preference implies that there may be a great deal of sensitivity to market place "dealing."

The market performance and firm conduct implications of brand preference are much less disconcerting, if the presence of a brand loyalty suggests only that buyers tend to have "favorites," but that the direction of brand favoritism is determined by market terms of trade. Observations in this study suggest that there may be a greater degree of inter-brand competition, in differentiated consumer product markets, than otherwise contemplated. Hopefully, the methododology employed here can be used in other experiments to understand more fully the effect of product differentiation on consumer choice and decision processes.

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[7] From Table 1, Column 5, this is the difference between 83.5 for III and 60.52 for II.

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# Credit Card Purchasing and Static Consumer Behavior Theory*

THOMAS L. SPORLEDER AND ROBERT R. WILSON

**This article treats the theoretical consequences of consumer credit card use. A delayed repayment model provides consumer optimization and indifference conditions between cash and credit card transactions. Under realistic interest and opportunity cost rates, consumers can rationally let a balance revolve about 39 percent of the time and maintain indifference over time.**

*Key words:* credit; consumer behavior; marketing.

CONSUMER CREDIT has been an important facet of retail purchases in the United States for many years. Availability of consumer credit has not been uniform among areas of retailing. Some areas such as sewing machines, pianos, and furniture have been constantly associated with some form of consumer credit for over a century. Others such as the retail gasoline industry have made consumer credit available only in recent years. Still other areas such as the retail food industry have fluctuated over the years with respect to existence, type, and quantity of consumer credit [1, pp. 1–3].

Even though credit cards are an important fact of life, little economic analysis exists which concerns their use. This article considers some theoretical consequences of consumer credit card availability in a static consumer behavior context. A previous treatment of consumer credit card use by Townshend-Zellner [5] provides a point of departure.

## Static Utility Analysis

Credit cards typically involve three relevant time periods: the initial period in which purchases are made, the period beginning with the close of the purchase period (billing date) and ending a specified time after the billing date during which outstanding balances may be liquidated without imposition of an interest charge, and the period for which interest charges must be paid on outstanding (revolved) balances.

A comparative statics approach can be utilized to analyze the effect of the opportunity for credit card purchasing on consumer's choice. A strictly quasi-concave utility function is postulated to hold for a single decision period corresponding to the period of purchasing under a credit card agreement. Utility is optimized subject to exogenous prices and resources (income) measured in dollars.

### A one commodity case

An oversimplified model which considers an economy with only one good allows the essence of the effects of credit cards on consumer behavior to be captured. Suppose only one good or service, $X$, exists that a consumer is interested in acquiring at any particular time. Further suppose that $Z$ and $Y$ are quantities of $X$ such that $Z$ may be purchased only with credit cards and $Y$ may be purchased only with cash. In this trivial situation, the indifference map is composed of straight lines since $Z$ and $Y$ are perfect substitutes. Both the indifference curves and budget restraint line have a negative unitary slope, are collinear, and the consumer is completely indifferent as to relative quantities of $Z$ and $Y$ (since they are the same commodity).

Assume the consumer exercises the full repayment option at the end of each period to avoid interest charges to the credit card company. The price of $X$ before and after the credit card purchasing possibility is then the relevant variable for investigation. Let $P_o$ $(=P_y)$ be the price of $X$ without the possibility of credit card purchasing and $P_w$ $(=P_z)$ be the price of $X$ with that possibility.

Let $i$ be the opportunity interest rate per time period on the consumer's dollar adjusted for any disutility associated with debt and $n$ be the number of time periods over which interest is compounded. If a positive rate of interest ($i > 0$) is compounded ($n > 0$), then $P_w$, the price of $X$ with credit card purchasing, is[1]

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[1] If disutility associated with indebtedness were

$$(1) \qquad P_w = P_o \left( \frac{1}{(1+i)^n} \right).$$

Since $n > 0$ and $i > 0$, it follows that $P_w < P_o$. In terms of indifference analysis, the price ratio is $(P_w/P_y) < 1.0$.

**Effect on price.**—When $i$ and $n$ are both positive, $P_w < P_o = P_y$. Of course, $Z$ and $Y$ are identical with or without the possibility of credit card purchasing. Therefore, the effect of credit card purchasing availability in a one-good economy is that price decreases by a factor in proportion to its present value as a result of the consumer's exercising the payment deferral inherent with a charge purchase, and the consumer has a choice between two prices for the same commodity.

The graphics of the analysis are also simple. The original budget restraint line and the indifference lines are collinear. After allowance for use of charge cards for $X$, the budget restraint line has a larger slope (in absolute value) and shifts as shown. A corner solution prevails after allowance for credit card use.[2]

If $n$ or $i$ is zero, the inequality $P_w < P_o$ will become an equality. If either $i$ or $n$ is zero, then the price of the good purchased with a credit card is the same as without it. The Townshend-Zellner [5] analysis holds for exactly this case. If $n$ and $i$ are positive, the price of $X$ and its present value price are not equal. The consumer will choose credit card or cash purchasing depending on which is the lowest in real cost.

**Effect on demand.**—For a one-good economy, it can be shown that the demand relationship is of the form $X = (I/P)$, a rectangular hyperbola in price ($P$) with income ($I$) as the hyperbolic parameter.[3] A decrease in price for this type economy implies an increase in quantity demanded, resulting in what Townshend-Zellner referred to as "upgrading."

sufficiently great or opportunities to invest dollars freed by deferred payments were sufficiently limited, $i$ might be negative or zero. Also, $n$ might be zero. If $i$ were negative, the credit card would never be used. Thus, it is sufficient to consider only cases in which $i > 0$ and $n > 0$. The analysis is, however, symmetric if $i < 0$ and $n > 0$.

[2] The substitution effects differ substantially from those derived for conventional demand theory and are difficult to separate from income effects. Due to space limitations, these effects are not detailed here but are available upon request to the authors.

[3] $P_x = I$ is the form of the constraint when optimizing $U(X)$ and is also a first order condition. Thus, $X = I/P$ is the form of the demand function for $X$ in a one-good economy. Whether or not a real price change occurs depends on the value of $n$ and $i$ as indicated earlier.

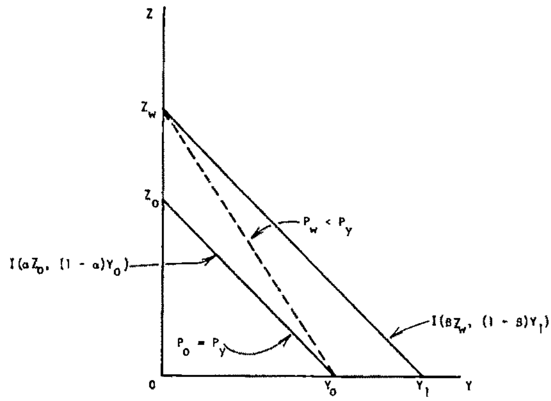


Figure 1. **Indifference map and budget restraint before and after credit card availability (where $0 \leq \alpha \leq 1$, $0 \leq \beta \leq 1$)**

With the option to use credit card purchasing or cash purchasing, the consumer is faced with two alternative real prices for each consumption choice. The first choice is the price ($P_o$ or $P_w$) the consumer is willing to pay and then the utility optimizing quantity.[4] The price choice is independent of the quantity choice. This is true since at the lower of two prices for the same commodity, the consumer can buy more of the commodity with the lower price than with the higher. Thus, the consumer will optimize by choosing the lower price as long as the marginal utility of the commodity is positive. For any commodity choice the lower price is optimal.

Once the minimal price alternative is chosen, the consumer can be viewed as treating price as a parameter in conventional utility analysis. That is, demand analysis becomes conventional after a minimal price has been selected. The recognition that prices to be paid can be chosen independently from the quantities taken may explain a significant portion of the shopping behavior of consumers. Shopping behavior, however, may not be as determinate as the credit card case since information theoretic considerations are likely involved [2, 3, 4].

## Many commodities

The one-good model described above can be expanded to one containing many commodities. Suppose that the $s$-dimensional vector $\overline{X}_o$ represents the optimal solution to a consumer's choice allocation in an economy without credit card

[4] After the means of payment have been chosen, the demand relationship is hyperbolic in price, as previously noted.

purchases. That is, the commodity choice $\overline{X}_o$, maximizes the utility function

$$U(X_1, \ldots, X_s) \tag{2}$$

subject to the constraint

$$\sum_{j=1}^{s} P_{oj}X_j = I, \tag{3}$$

where $P_{oj}$ is the price of $X$ without credit card purchases, $X_j$ is the $j^{th}$ commodity ($j = 1, \ldots, s$), and $I$ is personal disposable income. Now, suppose that credit card purchasing becomes available on the first $q$ commodities. Then, $X_1, \ldots, X_q$ can be charged, but $X_{q+1}, \ldots, X_s$ can only be bought with cash. The present value of the price of the first $q$ commodities is

$$P_{wj} = P_{oj}\left(\frac{1}{1+i}\right)^n < P_{oj} \tag{4}$$

for $j = 1, \ldots, q$ and $n > 0$, $i > 0$. $P_{wj}$ is the relevant price under the credit card terms. Also, note that the case in which $n > 0$ but $i \neq 0$ can be easily considered with this analysis.

The consumer may first choose to use the payment method under which prices are minimized. This choice is easily shown to be independent of decisions about optimal quantities taken after the minimal prices are chosen. It is sufficient to sketch the argument for the case in which the credit card option is associated with a lower real price than cash purchasing. The consumer's budget with cash purchasing is of the form

$$\sum_{j=1}^{s} P_{oj}\overline{X}_{oj} = I, \tag{5}$$

at the optimal point $\overline{X}_o$. A sequence of consumption expenditures is constructed by first allowing only cash, then one, two, and finally $q$ commodities to be purchased using a credit card as follows:[5]

(6)

$$C_0 = \sum_{j=1}^{s} P_{oj}\overline{X}_{oj} = I$$

$$C_1 = P_{o1}\left(\frac{1}{1+i}\right)^n \overline{X}_{o1} + \sum_{j=2}^{s} P_{oj}\overline{X}_{oj}$$

$$= P_{w1}\overline{X}_{o1} + \sum_{j=2}^{s} P_{oj}\overline{X}_{oj}$$

$$\vdots$$

$$C_{q-1} = \left(\frac{1}{1+i}\right)^n \sum_{j=1}^{q-1} P_{oj}\overline{X}_{oj} + \sum_{j=q}^{s} P_{oj}\overline{X}_{oj}$$

$$= \sum_{j=1}^{q-1} P_{wj}\overline{X}_{oj} + \sum_{j=q}^{s} P_{oj}\overline{X}_{oj}$$

$$C_q = \left(\frac{1}{1+i}\right)^n \sum_{j=1}^{q} P_{oj}\overline{X}_{oj} + \sum_{j=q+1}^{s} P_{oj}\overline{X}_{oj}$$

$$= \sum_{j=1}^{q} P_{wj}\overline{X}_{oj} + \sum_{j=q+1}^{s} P_{oj}\overline{X}_{oj}.$$

The sequence $C_0, C_1, \ldots, C_q$ is a monotonic decreasing sequence because $(1/1+i)^n < 1$. Therefore, $I = C_0 > C_1 > C_2 > , \ldots, > C_q$, since $U(X)$ is increasing in $X_{01}$ at $\overline{X}_o$ and $C_1 < I$. There exists a quantity of $X_1$, say $X_{w1} > \overline{X}_{o1}$, such that both

$$C_1 < P_{o1}\left(\frac{1}{1+i}\right)^n X_{w1} + \sum_{j=2}^{s} P_{oj}\overline{X}_{oj} \leq I \tag{7}$$

and

$$U(X_{w1}, \overline{X}_{o2}, \ldots, \overline{X}_{os}) > U(\overline{X}_{o1}, \ldots, \overline{X}_{os}). \tag{8}$$

Equations (7) and (8) mean that the optimal cash solution $\overline{X}_o$ can be improved if credit card purchasing (and lower present value price) is available for one of the commodities. This result holds immediately for an arbitrary number ($q$) of credit card and cash purchase commodities because of the monotonicity of the sequence. Once the optimal price alternative is chosen, it can be regarded as a parameter set by the consumer and an optimal allocation of the optimal budget can be accomplished in the manner of conventional economic theory.

Certain implications for empirical research result from this analysis. First, empirical demand

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[5] The reader is cautioned that the "sequence" referred to in the text is a *mathematical* sequence, not a time sequence. Each of the $q$ commodities are purchased at exactly the same point in time.

Also, implicit in the analysis is that the disutility associated with debt is assumed constant regardless of the magnitude of purchase. That is, $i$ is invariant for any $P_{oj}\overline{X}_{oj}$.

relationships must reflect the price associated with the payment method rather than the stated cash price (if different) in order to be theoretically consistent. Furthermore, a degree of "upgrading" in purchasing is to be expected if real prices from credit card purchasing are lower than cash prices. This results because more resources are available in the present period.

## Revolved Account Model

One feature of most credit card plans is the provision for delayed or revolved repayments in which payment for purchases in a current period may be made in some future period. The revolved account model relaxes the assumption that full repayment always occurs so as to avoid interest charges to the credit card company. By admitting revolved accounts, investigation of when repayment must occur to avoid credit card price becoming larger than cash option price is allowed. This represents a condition of suboptimal price choice. Clear from the previous analysis is that the cash price is the maximum price that a utility optimizing consumer would be willing to pay (in a static model) since the consumer would suffer a decrease in total utility if the credit card price exceeded the cash option price.

As before, if $i$ represents the opportunity cost interest rate on the consumer's dollar and $n$ is the number of periods that interest is compounded, then equation (4) can be adjusted as[6]

$$(9) \qquad P_{wj} = P_{oj}[(1+r)^m/(1+i)^n],$$

for

$$j = 1, \ldots, q,$$

where $r$ is the prevailing interest rate charged by the credit card company on revolved accounts. Also, $n = (m + c)$ for $0 \leq c \leq n$, where $n$ is the number of periods for which $i$ applies, $m$ is the number of periods for which rate $r$ applies, and $c$ is some constant which gives the average number of periods that credit balances may remain outstanding before an interest charge is incurred (i.e., $c$ is the average period lag between charge date and repayment date to avoid a revolved account).

Equation (9) expresses the new price of $X_j$ with a credit card but now assumes full repayment on a revolved account after m periods. The term $(1 + r)^m$ in equation (9) expresses the interest factor which is incurred on the revolved account.

[6] This analysis considers only purchases in a given period for expositional simplicity.

Note that the relationship between $n$ and $m$ depends on $c$. The value of $c$, and, therefore, the relationship between $n$ and $m$, is a function of two items: the distribution of purchases over a billing period, a possibly stochastic element; and the terms of the credit card company with respect to repayment before the account is considered revolved.

### Optimality condition

From the model development thus far, it is possible to define the conditions which optimize the consumer's position. Consumer optimization is defined as the minimization of the right-hand side of equation (9), given $P_{oj}$. Note that, given the constraints on the parameters of equation (9), $[(1+r)^m/(1+i)^n]$ must be positive. Thus, minimization of $P_{wj}$ would imply $m = 0$. Also, minimization of $P_{wj}$ would further imply maximization of $c$, given that $m = 0$. Since $c$ is a function of two items, only one of which the individual consumer controls directly, maximization of $c$ must be in terms of purchase pattern within a billing period given credit card company repayment terms.

This result is not surprising. It indicates that a consumer optimizes by never allowing the account to revolve. By so doing, the consumer avoids any interest payment to the credit card company.

### Indifference condition

The maximum number of periods that a consumer could afford to leave a given period's purchases unpaid can also be determined from the model. Clearly, if the present value price of charged merchandise becomes greater than the price of merchandise not charged, a rational consumer would not make charge purchases (again, a corner solution).

The consumer will be indifferent between credit card purchases and purchases without the availability of credit whenever $P_{wj} = P_{oj}$, for $j = 1, \ldots, q$. This equality holds if and only if $(1 + r)^m = (1 + i)^n$. As noted above, the rational consumer would prefer that $P_w < P_o$, but the indifference condition $(1 + r)^m = (1 + i)^n$ is useful for analytic purposes.

The indifference condition can be solved for $m$ and $n$ given the level of $c$ by

$$(10) \quad m \ln(1 + r) = (m + c) \ln(1 + i).$$

**An example.**—The revolved account model can best be understood by utilizing some hypothetical yet realistic values for $c$, $r$, and $i$. Sup-

pose that the period under consideration is one month, and the interest charge on a revolved account is 18 percent per annum, the opportunity cost factor is set at 5 percent per annum, and the average period lag between purchase and revolve date is one month. Thus, $r = 1.5$ percent, $i = 0.42$ percent, and $c = 1.0$. Using these values yields $m = 0.39$ and $n = 1.39$ for the indifference condition.

Interpretation of $m$ and $n$ in this case is quite simple. Under the assumption that $m$ and $n$ are continuous, results from equation (10) imply that the indifference condition occurs 0.39 months into the first month revolvement. The interpretation under the more realistic case that $m$ and $n$ are discrete suggests that the consumer can rationally let a balance revolve once (i.e., $m = 1$) about 39 percent of the time and maintain indifference over time.

**Parameter sensitivity.**—Another question of interest with this model is the sensitivity of the indifference condition with respect to various parameter values. Under most circumstances, when periods are in months, the upper bound on $c$ can be considered to be 1.83 (one month, 25 days) and the lower bound 0.5 (about 15 days). Therefore, for the delayed repayment model, the sensitivity of $r$ and $i$ is examined with the constraints $0.5 \leq c \leq 1.83$. Within these bounds the corresponding $m$ and $n$ values are computed.

From the first two portions of Table 1, for $c = 0.75$ the indifference condition for the $n$ value is 1.04 months if $i = 0.42$ but is 1.36 months for $i = 0.67$. The same is true for decreasing $r$. If the $r$ decreases to 12 percent per annum compared to 18 percent, given $c = 0.75$, then the indifference condition increases from 1.04 months for $n$ for the higher interest rate to 1.30 months for the lower rate.

In general, $m$ and $n$ are more sensitive to changes in $i$ than $r$ when compared on an equal change basis. This further implies that there are likely significant differences among individuals with respect to their indifference position since $i$ reflects any disutility which may be associated with the use of credit cards for purchasing (i.e., $i$ is more volatile than $r$).

**Table 1. Revolved account model indifference conditions for selected $r$ and $i$, monthly periods**

| $c$ | $m$ | $n$ |
|---|---|---|
| | $r = 1.5\%, i = 0.42\%$ | |
| 0.5 | 0.20 | 0.70 |
| 0.75 | 0.29 | 1.04 |
| 1.0 | 0.39 | 1.39 |
| 1.25 | 0.49 | 1.74 |
| 1.5 | 0.59 | 2.09 |
| 1.75 | 0.69 | 2.44 |
| 1.83 | 0.72 | 2.55 |
| | $r = 1.5\%, i = 0.67\%$ | |
| 0.5 | 0.41 | 0.91 |
| 0.75 | 0.61 | 1.36 |
| 1.0 | 0.81 | 1.81 |
| 1.25 | 1.02 | 2.27 |
| 1.5 | 1.22 | 2.72 |
| 1.75 | 1.42 | 3.17 |
| 1.83 | 1.49 | 3.32 |
| | $r = 1.0\%, i = 0.42\%$ | |
| 0.5 | 0.36 | 0.86 |
| 0.75 | 0.55 | 1.30 |
| 1.0 | 0.73 | 1.73 |
| 1.25 | 0.91 | 2.16 |
| 1.5 | 1.09 | 2.59 |
| 1.75 | 1.27 | 3.02 |
| 1.83 | 1.33 | 3.16 |

## Limitations

The entire analysis is couched in a static framework. A static analysis of credit card influences on consumer behavior cannot be complete. Dynamic demand and time preferences would yield more complete analysis.

Another limitation concerns the additional assumption required for the above analysis that the consumer will save accumulated balances accruing from credit purchases. In addition, any "vexation costs" which may be attached to managing accumulated balances is not considered.

## Conclusions

A major conclusion from the analysis is that, given two alternative price sets for a set of commodities, the choice of a minimal price is independent of and logically prior to any quantity choices that are under consideration. After the minimal pricing alternative has been obtained the consumer then treats the chosen pricing alternative as a parameter and makes an optimal quantity choice.

The delayed repayments model focuses on the possibility that a consumer may make credit card purchases but revolve the account. This model defines both an optimality and indifference

condition. The optimality condition implies the consumer should never let an account revolve and should make purchases through time so as to maximize the lag between charge date and the repayment date which avoids a revolved account. The indifference condition suggests that a consumer can rationally let a balance revolve once about 39 percent of the time and maintain indifference over time, assuming realistic interest rates and opportunity costs. Also, the indifference condition is more sensitive to changes in the opportunity cost rate than changes in the interest rate.

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# Spatial Price Differentials for Corn among Illinois Country Elevators

LEROY DAVIS AND LOWELL HILL

**Corn price differentials among country elevators often exceed norms of perfect competition. Identification of causal factors may suggest remedial policy decisions. This study indicates that the variables of seasonal adjustments, local demand and supply conditions, availability of transportation facilities, and government loan rate are significant influences in price variation.**

***Key words:*** **price differentials, country elevator, corn prices, market structure.**

WITHIN THE LIMITS of the perfect market as defined by Shepherd, prices should differ among locations by no more than the cost of transportation; among time periods by no more than the cost of storage; and among product forms by no more than the cost of transformation [13, pp. 19–25]. Examination of pricing patterns, even in a market as highly developed as the grain market, reveals price differentials that cannot be readily explained by these three cost factors [4, p. 53; 5, p. 2]. Designating these differences as market imperfections [6, p. 607] does little to identify the cause of the aberrations or to suggest possible solutions. There is little opportunity for improving performance unless the causal factors can be isolated and the malleable dimensions [15, pp. 401–402] of structure and conduct can be identified. The objective of the research reported in this paper was to explain price differentials among country elevators in Illinois and to identify the extent of market imperfections associated with them.

## Data

The Market News Service of the Illinois Department of Agriculture maintains daily price records from a sample of country elevators selected to represent all geographical areas of the state. The manager of each of these elevators was interviewed to obtain data on the characteristics of each firm and its markets. Complete data were obtained on 41 elevators distributed throughout the state. These data were supplemented by production and marketing data published for each county.

To keep the problem within manageable dimensions, only the spatial aspects were considered in this study. Daily price variation at individual elevators is highly correlated during the periods of major movements. Aberrations on particular days may be caused by any of a number of conditions so specific to the day and the elevator as to make data collection infeasible. For example, equipment breakdown, inability to schedule transportation, and severe weather conditions are often the basis for price changes. Focus of the research was, therefore, on explaining differences in average prices over a period of time of sufficient length to eliminate these minor variations. Annual data were divided into several periods for the purpose of identifying different market situations.

To assure uniformity of the product being priced, price was specified as the price for No. 2 yellow corn, offered to farmers on each day. Differentials in discounts and grading procedures also enter into the actual net prices received by a farmer. However, the No. 2 basis indicates the price for a specific standardized product—a price that could have been received by anyone delivering corn meeting the Federal Standards for this grade. Higher discounts are sometimes used to off-set a higher base price, especially during seasons when very little No. 2 corn can be delivered. In this study the level of discounts was used as an independent variable rather than an adjustment in price in order to avoid biases caused by the aggregation of prices weighted by number of bushels purchased at various discounts. The problem of bids at which no corn was ever purchased was recognized, but no solution was apparent with the data available.

## Economic Relationships

The cause of price variability among country elevators may be classified in four general categories:

1. Differences in availability and cost of transportation
2. Differences in operating costs

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3. Differences in local demand and supply conditions
4. Market power.

Categories 1, 2, and 3 provide an economic rationalization for price differentials [7, 13]; category 4 would ordinarily be considered a result of market imperfections. One of the objectives of this study was to identify the extent to which price variability is explainable by each of the above categories of variables.

Market structure theory indicates that some elements of geographical monopsony exist in the elevator industry by virtue of the spatial relationships among firms [9]. The extent to which this provides market power depends not only on physical distances from producer to an elevator and competing firms but on the farmers' opportunity costs and actual costs involved in delivering grain at various seasons of the year. Consequently, perfect competition does not provide a satisfactory norm for evaluation of performance in this industry where economies of size dictate firms with specific market areas competing for product only at the periphery of the market area. An alternative method of evaluation is to identify those factors that explain price differentials among firms and determine which if any of these factors constitute a barrier to improved economic performance.

### Transportation costs

Of the four categories of variables listed above, transportation is the one most frequently used in explaining geographical differences in price. Spatial prices in the perfect market would be assumed to differ by no more than the cost of transportation between any two points [1]. This should not be accepted as evidence of adequate performance without a more detailed explanation, because price differentials well within the limits of transfer costs may still represent monopsony profits (i.e., profits above the required returns to factors) of a magnitude greater than the acceptable norms of workable competition [15, p. 385]. Transportation cost between two points is often several times larger than the gross margin of the elevator at either of the points [4, p. 51]. In addition, transportation cost is a valid measure of the limits of price differentials between two elevators only if grain can logically flow from the low-price point toward the high-price point. Ultimate destination and use, cost of handling and routing for transshipment, and seasonal fluctuations in storage space often make shipment between two particular points infeasible despite a price differential greater than the cost of transportation.

### Operating costs

Differences in operating costs among elevators can be reflected in price differences only if there is a degree of monopsony power present. Under perfect competition, the producer would presumably sell to the highest bidder with no knowledge of or interest in the costs of operation. Differences in costs would have to be absorbed in the returns to one of the fixed factors of production. Many of the variables in this study were indicators of or closely associated with costs of operation. Utilization of space, volume of business, production density, and type of firm should all reflect differences in operating costs and efficiency. To the extent that these explain price differences, they are evidence of market power.

### Demand and supply

Local demand and supply conditions may also affect prices paid to farmers. Elevators with direct access to a higher priced market or located in an area of high livestock demand may have seasonal opportunities for sales that can be passed on to farmers in the form of higher prices [10]. Fluctuations in local supply relative to other regions or time periods are reflected in prices, especially if fixed resources cannot be adjusted to match the supply on hand. Response to seasonal supply is evidenced by depressed prices at harvest in a larger than usual production year [5, p. 2].

## Statistical Analysis

Specific variables used in the analysis are shown in Table 1. The three dependent variables were designated as $Y_1$ to $Y_3$ and represent average prices bid to farmers by each elevator in the sample during three selected time periods. Many of the 40 independent variables ($X_1$ to $X_{40}$) were highly correlated and required some means of reduction to a manageable number of variables that were statistically independent.

### Raw data regression models

Two regression models were estimated using the raw data as independent variables. The results of these estimates are given in Table 2. In the first estimate, the annual average bid price quoted at country elevator stations was

Table 1. List of variables

| Symbolic variable | Description of variable | Unit of measurement | |
|---|---|---|---|
| $X_1$ | Ownership of elevator | Cooperative | $=0$ |
| | | Private | $=1$ |
| $X_2$ | Number of plants, elevator type | Single plant elevator | $=0$ |
| | | Line elevator | $=1$ |
| $X_3$ | Number of rail outlets to market | Number | |
| $X_4$ | Functional type of firm | Country elevator | $=0$ |
| | | Sub-terminal | $=1$ |
| $X_5$ | Grain supply source | Farmers only | $=0$ |
| | | Farms and elevators | $=1$ |
| $X_6$ | Grain sales | Farmers and terminals | $=1$ |
| | | Terminal only | $=0$ |
| $X_7$ | Elevator stored grain for CCC | No | $=0$ |
| | | Yes | $=1$ |
| $X_8$ | Percent of gross income from grain | Percent | |
| $X_9$ | Total storage capacity | Thousand bushels | |
| $X_{10}$ | Percent of total capacity that is upright | Percent | |
| $X_{11}$ | Turnover rate | Total annual receipts/$X_9$ | |
| $X_{12}$ | Average annual utilization of storage space | Percent | |
| $X_{13}$ | Grain receiving rate | Hundred bushel per hour | |
| $X_{14}$ | Ownership of a dryer | No | $=0$ |
| | | Yes | $=1$ |
| $X_{15}$ | Grain shipping rate | Hundred bushel per hour | |
| $X_{16}$ | Volume of corn dried | Thousand bushels | |
| $X_{17}$ | Operating expenditures | Thousand dollars | |
| $X_{18}$ | Depreciated book value of elevator | Thousand dollars | |
| $X_{19}$ | Size of the supply area | Radius in miles | |
| $X_{20}$ | Number of the markets regularly shipped to by rail | Number | |
| $X_{21}$ | Number of buyers who regularly give daily bids | Number | |
| $X_{22}$ | Number of competing plants within 10 mile radius | Number | |
| $X_{23}$ | Hedged grain regularly | No | $=0$ |
| | | Yes | $=1$ |
| $X_{24}$ | Moisture discount rate | Cents per bushel | |
| $X_{25}$ | Merchandizing margin | Cents per bushel | |
| $X_{26}$ | Total annual grain receipts | Thousand bushel | |
| $X_{27}$ | Rail rate to principal railshipping market outlet | Cents per bushel | |
| $X_{28}$ | Truck rate to principal truckshipping market | Cents per bushel | |
| $X_{29}$ | Principal mode of transport | Railroad | $=0$ |
| | | Other | $=1$ |
| $X_{30}$ | Location of primary market outlet | Within state | $=0$ |
| | | Out of state | $=1$ |
| $X_{31}$ | Supply consumption relationships | Surplus | $=0$ |
| | | Deficit | $=1$ |
| $X_{32}$ | Type of production area | Cash grain | $=0$ |
| | | Other | $=1$ |
| $X_{33}$ | Support price in county | Cents per bushel | |
| $X_{34}$ | Number of price support loans in the county | Number | |
| $X_{35}$ | Value of price support loans in the county | Thousands of dollars | |
| $X_{36}$ | Density of production in the county | Bushels/acre of farm land | |
| $X_{37}$ | Yield per acre | Bushel/acre of corn | |
| $X_{38}$ | Barge shipment | Yes | $=0$ |
| | | No | $=1$ |
| $X_{39}$ | Percentage of shipments by rail | Percent | |
| $X_{40}$ | Percentage of volume shipped to in-state destinations | Percent | |
| $Y_1$ | Average bid price of corn: harvesting period | Cents per bushel | |
| $Y_2$ | Average bid price of corn: distribution period | Cents per bushel | |
| $Y_3$ | Average bid price of corn: diminishing supply period | Cents per bushel | |

Table 2. Comparison of actual average prices and average deviation prices in regression for the distribution period

| Symbolic variable | Description of variable | Actual average price model: Regression coefficient | Standard error | t statistic | Average deviation price model: Regression coefficient | Standard error | t statistic |
|---|---|---|---|---|---|---|---|
| | | (cents/bu) | (cents/bu) | | (cents/bu) | (cents/bu) | |
| $X_0$ | Intercept | 6.157 | | | 119.600 | | |
| $X_2$ | Elevator type | 1.056 | 1.008 | 1.047 | −1.025 | 1.013 | −1.012 |
| $X_5$ | Grain supply source | 2.562 | 0.792 | 3.235 | −2.473 | 0.795 | −3.110 |
| $X_8$ | Percent of gross income from grain | 0.039 | 0.096 | 0.405 | −0.042 | 0.042 | −0.437 |
| $X_{11}$ | Turnover rate | 0.068 | 0.172 | 0.396 | −7.431 | 0.172 | −0.431 |
| $X_{12}$ | Average annual utilization of storage space | −0.289 | 2.172 | 0.133 | −0.577 | 2.179 | −0.265 |
| $X_{14}$ | Ownership of a dryer | −0.529 | 1.812 | −0.292 | 0.359 | 1.818 | 0.197 |
| $X_{17}$ | Operating expenditure | 0.0017 | 0.0013 | 1.364 | −0.0014 | 0.0013 | −1.077 |
| $X_{22}$ | Number of competing plants within 10 mile radius | −0.286 | 0.126 | −2.272 | 0.272 | 0.127 | 2.147 |
| $X_{23}$ | Hedge grain regularly | 0.779 | 0.617 | 1.262 | −0.736 | 0.619 | 1.189 |
| $X_{30}$ | Location of primary market value | 0.633 | 0.726 | 0.871 | −0.599 | 0.730 | −0.821 |
| $X_{32}$ | Type of production area | 0.158 | 0.631 | 0.250 | −0.161 | 0.633 | −0.254 |
| $X_{33}$ | Support price | 1.050 | 0.240 | 4.365 | −1.045 | 0.241 | −4.331 |
| $X_{38}$ | Barge shipment | −4.499 | 2.004 | −2.245 | 4.640 | 2.012 | 2.306 |
| $X_{39}$ | Percent of volume shipped by rail | 0.665 | 1.164 | 0.572 | −0.593 | 1.169 | −0.507 |

| | Standard error of estimate | $R$ | $R^2$ | $F$-ratio (multiple $R$) |
|---|---|---|---|---|
| Actual average price model | 1.586 | .906 | .821 | 8.539 |
| Deviation price model | 1.592 | .901 | .812 | 8.030 |

the dependent variable. In the second model, an annual average deviation price was used as the dependent variable. Deviation prices were computed by subtracting each elevator daily bid price from the Chicago cash price on the same day. Fourteen independent variables were selected from the 40 to minimize intercorrelations while retaining those variables with the highest correlation with the daily bid prices in the 40 × 40 correlation matrix. The same 14 independent variables were used in both models.

Fairly good estimates of price variation among the elevators were obtained in both models—$R^2$'s of .82 and .81. However, only 4 of the 14 independent variables were significantly different from zero in each model. The same four variables were significant in each estimate. There appeared to be no significant differences between the two models, although the actual price model gave a slightly better estimate. Because of multicollinearity among the independent variables, it was necessary to introduce factor analysis to group the variables into independent composite sets.[1]

## Grouping of variables by factor analysis

By combining the variables into indices (factor scores) via principal axis factor analysis, some desirable analytical and statistical prop-

[1] The principles and techniques of factor analysis as used in this paper are described in a number of texts and articles including [3, 8, 11, 12, 14, 16, 17].

erties are obtained: (1) the large number of independent variables is reduced to a small set of hypothetical constructs while retaining the influence of all 40 variables in the model for a given number of observations; (2) the smaller number of variables increases the degrees of freedom in the regression model for a given set of observations; (3) collinearity among the explanatory variables is totally eliminated; and (4) some unobserved traits of the data may be revealed as a result of the procedure [8, 12].

A partial list of the factors extracted from the matrix of correlation coefficients is shown in Table 3. The total of 40 factors identified by the principal axis factor analysis was reduced to 13 by using the rule of thumb suggested by Wells and Sheth [2, 18]. The factors in Table 3 are listed in decreasing order of magnitude of the eigenvalues. Since the 14th factor and all succeeding factors have eigenvalues of less than one, they were deleted from the regression models used for the remainder of the analysis. Factors 14 and 15 have been retained in Table 3 to illustrate the decreasing eigenvalues and percent of variance. The variance column is obtained by dividing the eigenvalue by the trace of the variance-covariance matrix. Since the variance of each factor is equal to one, the divisor is equal to the number of factors (40) used in this model.

The matrix of factor loadings (coefficients) was rotated using varimax rotation—an orthogonal transformation of the coefficients that maximizes the square of the variance between the factor loadings. Hence, the factor loadings will tend toward zero and one [8]. Table 4 shows the factor loadings between each variable and one of the factors (the loading coefficients of each variable on the other factors are omitted for the sake of clarity of exposition). This procedure provides a basis for grouping the variables and permits representation of a set of variables by a single index called a "factor score" [12]. These factor scores serve as input data for a regression equation. Examination of the factor loadings of individual variables on each factor identified a common attribute for each factor [8]. The descriptive name given each factor is suggestive of the interrelationships that were identified.

Table 3. Partial list of eigenvalues and relative variances associated with significant factors

| Factors | Eigen value | Percent of variance | Cumulative percent of variance |
|---|---|---|---|
| $F_1$ | 7.699 | 19.247 | 19.247 |
| $F_2$ | 6.461 | 16.153 | 35.400 |
| $F_3$ | 3.247 | 8.117 | 43.517 |
| $F_4$ | 2.543 | 6.359 | 49.875 |
| $F_5$ | 2.152 | 5.379 | 55.254 |
| $F_6$ | 2.006 | 5.014 | 60.268 |
| $F_7$ | 1.672 | 4.180 | 64.448 |
| $F_8$ | 1.611 | 4.028 | 68.476 |
| $F_9$ | 1.440 | 3.601 | 72.077 |
| $F_{10}$ | 1.175 | 2.938 | 75.015 |
| $F_{11}$ | 1.152 | 2.879 | 77.893 |
| $F_{12}$ | 1.098 | 2.744 | 80.638 |
| $F_{13}$ | 1.024 | 2.559 | 83.197 |
| $F_{14}$ | 0.862 | 2.155 | 85.352 |
| $F_{15}$ | 0.850 | 2.125 | 87.477 |

### Time periods in the model

Prices paid for corn by country elevators were divided into five time periods to provide more nearly homogeneous relationships for the regression analyses. Specific seasons were determined by principal axis factor analysis in which each of the 251 marketing days between September 1, 1969, and August 31, 1970, were used as variables and the 41 elevators in the sample were used as observations. The factors listed in Table 5 represent seasons of common price variability and each variable (day of the year) was assigned to a factor on the basis of the magnitude of the variance accounted for by a given factor. These groupings were identified by orthogonally rotating the matrix using five factors and 251 factor loadings.[2]

Only the three seasons of harvesting period, distribution period, and diminishing supply period were used in the regression models. Period 1 and period 5 were discarded because of the speculative influence of new crop price estimates during this time. Daily prices bid to farmers for No. 2 corn were averaged for these 41 elevators for each of the three selected time periods. These average prices became the dependent variables for the three regression models described in the following section.

### Multiple regression using factor scores

A multiple regression model was employed in estimating the quantitative relationships between

[2] The first five factors account for 89 percent of total variance due to seasonality, and the additional factors account for relatively little of the total variance.

Table 4. Rotated matrix factor loadings of market structure variables[a]

| Variable | Factor $F_1$ | $F_2$ | $F_3$ | $F_4$ | $F_5$ | $F_6$ | $F_7$ | $F_8$ | $F_9$ | $F_{10}$ | $F_{11}$ | $F_{12}$ | $F_{13}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_{25}$ | −.46 | | | | | | | | | | | | |
| $X_{31}$ | −.77 | | | | | | | | | | | | |
| $X_{33}$ | −.50 | | | | | | | | | | | | |
| $X_{34}$ | .92 | | | | | | | | | | | | |
| $X_{35}$ | .93 | | | | | | | | | | | | |
| $X_{36}$ | .64 | | | | | | | | | | | | |
| $X_{37}$ | .71 | | | | | | | | | | | | |
| $X_9$ | | .74 | | | | | | | | | | | |
| $X_{13}$ | | .75 | | | | | | | | | | | |
| $X_{15}$ | | .89 | | | | | | | | | | | |
| $X_{16}$ | | .66 | | | | | | | | | | | |
| $X_{17}$ | | .42 | | | | | | | | | | | |
| $X_{18}$ | | .78 | | | | | | | | | | | |
| $X_{26}$ | | .75 | | | | | | | | | | | |
| $X_{19}$ | | | .75 | | | | | | | | | | |
| $X_{20}$ | | | .82 | | | | | | | | | | |
| $X_{21}$ | | | .86 | | | | | | | | | | |
| $X_{22}$ | | | .34 | | | | | | | | | | |
| $X_{27}$ | | | | .50 | | | | | | | | | |
| $X_{28}$ | | | | .70 | | | | | | | | | |
| $X_{30}$ | | | | .72 | | | | | | | | | |
| $X_{40}$ | | | | −.71 | | | | | | | | | |
| $X_5$ | | | | | .46 | | | | | | | | |
| $X_{24}$ | | | | | .68 | | | | | | | | |
| $X_7$ | | | | | | .84 | | | | | | | |
| $X_{11}$ | | | | | | .86 | | | | | | | |
| $X_{29}$ | | | | | | | −.8[illegible] | | | | | | |
| $X_{39}$ | | | | | | | .8[illegible] | | | | | | |
| $X_3$ | | | | | | | | .68 | | | | | |
| $X_{32}$ | | | | | | | | −.54 | | | | | |
| $X_2$ | | | | | | | | | −.78 | | | | |
| $X_4$ | | | | | | | | | .75 | | | | |
| $X_1$ | | | | | | | | | | .78 | | | |
| $X_8$ | | | | | | | | | | .49 | | | |
| $X_{14}$ | | | | | | | | | | −.56 | | | |
| $X_6$ | | | | | | | | | | | .82 | | |
| $X_{23}$ | | | | | | | | | | | .64 | | |
| $X_{10}$ | | | | | | | | | | | | −.64 | |
| $X_{12}$ | | | | | | | | | | | | .61 | |
| $X_{38}$ | | | | | | | | | | | | | .93 |

[a] Only one factor loading is shown for each variable in order to simplify the visual relationships. In general, loadings deleted from the table were smaller than those shown.

the price variables and the factor scores which are composed of market structure variables. The model with factor scores is expressed as follows:

$$Y_t = \sum_{i=1}^{13} b_i S_i + U_t$$

where $i$ = variables 0, 1, 2, . . . . . . 13, and $t$ = time periods 1, 2, 3.

The dependent variable $Y_t$ is the average price of No. 2 corn at grain elevators at time $t$, and $U_t$ is the associated error term. The term $b_o S_o$ is the intercept of the dependent variable. The $b_i$'s are the coefficients to be estimated, and the $S_i$'s are independent variables which explain variations in $Y_t$. This model gives a better estimate of the regression relationships—specifically higher $R^2$'s and a larger number of significant variables—than the models using raw variables.

Table 5. Factors and variance in seasonal price movements and seasonal time periods

| Factor | Eigenvalue | Percent of variance | Cumulative percent of variance |
|---|---|---|---|
| $F_1$ | 150.50 | 60.20 | 60.20 |
| $F_2$ | 46.93 | 18.77 | 78.97 |
| $F_3$ | 11.87 | 4.75 | 83.72 |
| $F_4$ | 7.59 | 3.04 | 86.75 |
| $F_5$ | 5.36 | 2.15 | 88.90 |
| $F_6$ | 3.42 | 1.37 | 90.27 |

| Time period | Beginning date | Ending date |
|---|---|---|
| New crop adjustment (1969) | September 1, 1969 | September 15, 1969 |
| Harvesting | September 16, 1969 | December 31, 1969 |
| Distribution | January 5, 1970 | May 18, 1970 |
| Diminishing supply | May 19, 1970 | July 27, 1970 |
| New crop adjustment (1970) | July 28, 1970 | August 31, 1970 |

## Results of the Analysis

Three regression models were estimated using the average price during each of the three time periods as the respective dependent variables and the 13 computed factor scores as independent variables. Each elevator constituted an observation; the values for each observation on the independent variables were the same in each of the three models. Regression coefficients and $t$-statistics are shown in Table 6.

Results of all three models indicate that most of the important variables have been identified in the factor scores regression model. Model 1, for the harvesting period, has a lower $R^2$ and a lower $F$-ratio of the multiple $R$ than the models of the other two periods. Only five of the variables have coefficients that are statistically significant at the 5 percent level in explaining variations in prices during the harvesting season.

The local supply factor ($S_1$) is composed of several variables reflecting local conditions of supply, including yield ($X_{37}$), production density ($X_{36}$), and feed surplus deficit area ($X_{31}$). The

Table 6. Regression relationships between average price of corn during harvesting, distribution, and diminishing supply periods and market structure variables

| Symbolic variable | Descriptive label of the factor | Model 1 Regression coefficient[a] | Model 1 t statistic | Model 2 Regression coefficient | Model 2 t statistic | Model 3 Regression coefficient | Model 3 t statistic |
|---|---|---|---|---|---|---|---|
| | | (cents/bu) | | (cents/bu) | | (cents/bu) | |
| $S_0$ | Intercept | 108.42 | | 117.680 | | 128.680 | |
| $S_1$ | Local supply | −1.055 | −3.642 | −1.431 | −6.427 | −0.837 | −3.262 |
| $S_2$ | Size of firm | −0.335 | −1.157 | −0.403 | −1.811 | −0.359 | −1.399 |
| $S_3$ | Local demand | 0.801 | 2.765 | 0.812 | 3.646 | 0.478 | 1.864 |
| $S_4$ | Transport rate | 0.797 | 2.748 | 1.287 | 5.782 | 1.142 | 4.449 |
| $S_5$ | Product quality | 0.365 | 1.260 | 0.092 | 0.414 | 0.288 | 1.121 |
| $S_6$ | Grain movement | −0.221 | −0.762 | −0.548 | −2.461 | −0.428 | −1.667 |
| $S_7$ | Transport mode | −0.386 | −0.133 | 0.377 | 1.693 | 0.266 | 1.035 |
| $S_8$ | Production area | 0.381 | 1.316 | 0.597 | 2.680 | 0.401 | 1.564 |
| $S_9$ | Elevator type | 0.553 | 1.908 | 0.756 | 3.394 | 0.287 | 1.118 |
| $S_{10}$ | Farm service | −0.980 | −3.383 | −1.050 | −4.718 | −1.243 | −4.843 |
| $S_{13}$ | Barge shipment utilization | −0.468 | −1.614 | −0.583 | −2.617 | −0.528 | −2.055 |
| $S_{11}$ | Risk avoidance | 0.492 | 1.698 | 0.139 | 0.621 | 0.294 | 1.146 |
| $S_{12}$ | Storage space | −0.893 | −3.080 | −0.477 | −2.143 | −0.535 | −2.083 |

| | Standard error of estimate | Regression coefficient | $R^2$ | $F$-ratio (multiple $R$) |
|---|---|---|---|---|
| Model 1 | 1.856 | .838 | .702 | 4.906 |
| Model 2 | 1.426 | .922 | .850 | 11.784 |
| Model 3 | 1.644 | .862 | .743 | 5.999 |

[a] The standard errors of the regression coefficients are constant for all variables in each model; for models 1, 2, and 3, respectively, the standard errors of regression coefficients are 0.290, 0.223, and 0.258.

sign of the coefficient is consistent with the theoretical hypothesis. This factor also includes the level of price supports for corn in the county ($X_{33}$), the total value of support loans ($X_{35}$), and the number of support loans issued ($X_{34}$). These affect the supply of "free" corn available for sale through the elevator. Merchandizing margin ($X_{25}$) was also loaded on this factor due to the high correlation between competitive gross margins and production density.

The local demand factor construct is also significant in this model and includes variables such as the number of buyers who give daily bids and the number of markets regularly shipped to by rail. Prices paid to farmers tend to be higher at those elevators where demand (as measured by the above variables) is greater.

The significant, positive coefficient for transportation rate to the primary market ($S_4$) indicates that this is not a measure of the cost of moving grain but a proxy variable indicating the availability of distant markets. Nearly all grain is sold from Illinois' country elevators on the basis of on-track, in freight cars at the country elevator (track country station), which means that the freight is paid by the buyer. Therefore, the freight rate influences the farmer's price only through the indirect route of the bid to the elevator. This relationship suggests that elevators with access to distant markets receive higher bids and can offer higher prices to farmers.

The negative coefficient for the factor representing services to farmers ($S_{10}$) is significant at the 5 percent level in all three models. The signs associated with the three variables loaded on $F_{10}$ suggest that diversified cooperative firms providing drying services pay higher prices for grain. This may reflect the basic philosophy of firms trying to serve the farmers' needs. It may also indicate that functions other than grain merchandizing, such as grain drying and feed and fertilizer sales, are subsidizing the low merchandizing margins experienced by the grain trade during the time period of the study. The size and the significance level of the coefficient for $S_{10}$ increases between model 1 and model 2. During the more competitive post harvest period, the diversified co-ops providing services to farmers are in a better financial position to lower margins in a competitive struggle to attract farm stored grain.

The advantage of low cost transportation is evident in $S_{13}$. Those elevators shipping grain by water paid higher prices for corn than those having access only to truck and rail transport.

These same five variables were significant in the second model where the dependent variable was the average price during the distribution period of the marketing year. A greater percent of variation was explained in this model, and four additional coefficients were significant at the 5 percent level—$S_6$, $S_8$, $S_9$, and $S_{11}$.

The factor representing the internal grain movement of the elevator includes the volume of corn stored for *CCC* and turnover rate. This variable was significant only during the distribution period, and the negative coefficient indicates that elevators with a higher rate of turnover of space tended to pay lower prices for corn during this period. This coefficient can also be interpreted as indicating that those elevators with little or no *CCC* grain in storage were willing to bid higher prices to farmers in order to fill empty storage space.

The production area factor ($S_8$) is also significant for the season of distribution only. Variables included in this factor are the number of market outlets available to the firm for rail shipment and the type of farming in the production area. This factor describes the characteristics of the geographical location with respect to availability of cash grain and alternative outlets. During the period of greater competition for supplies, a firm with alternative rail outlets and a continuing supply of cash grain out of farm storage has a relative advantage that is reflected in higher prices.

The type of elevator is a significant factor in the distribution time period only. The two variables used to differentiate type were (1) single plant cooperative or independent elevators vs. multiple plant line elevators and (2) country elevators buying only from farmers vs. subterminal elevators. Single plant firms and subterminal elevators tended to offer higher prices to farmers during the distribution period, but prices during the other two periods were not significantly different at the 5 percent level.

Elevators that sold grain on local markets (e.g., to livestock feeders) and had no hedging operations (factor $S_{11}$) paid lower prices to farmers. This probably reflects a lack of market opportunities and, more important, the cost of higher risk incurred in unhedged inventories. The sign of variable $X_{23}$ was consistent with this conclusion in the raw variable regression of Table 2. This variable was not significant during the harvesting season probably because the rapid turnover during the harvest and the fairly consistent pattern of rising prices following harvest reduced the risk of price declines on grain storage.

During the diminishing supply period, five variables were significant. Factors $S_1$, $S_4$, $S_{10}$, and $S_{13}$ were significant as in the other 2 models. However, local demand dropped out of the list of significant variables, indicating a lesser importance of the number of bids as the storage supplies diminish.

## Implications

Many of the significant variables that explain variation in prices over geographical space are outside the control of the individual elevator. For example, the availability of water transportation and the supply of corn available for purchase must in general be taken as given in managerial decision models. In addition it is difficult to visualize short-run policy recommendations that would alter many of the variables that affect market performance. Production density is closely related to economies of size, average costs, and prices paid to farmers. This situation can be changed by increased regional specialization of production, but these changes are made very slowly and the costs of fixed production and marketing resources must be considered in any recommendation for change.

Differences among the three periods suggest that the price competition among the elevators is decreased during the harvest period as indicated by greater unexplained variance. The coefficient for local supply is larger in absolute terms during the distribution period as are the coefficients for transport rate and grain movement. The level of statistical significance was also higher for these variables. These three factors reflect marketing costs of the elevator through their effect on volume of corn, turnover, and transportation cost. Only to the extent that a firm has a geographical monopsony can it use cost as a basis for setting price. Competition among elevators for a fixed supply of corn will force all prices to the highest price of any firm. Higher cost firms will suffer short run losses or lower returns to their resources. During the harvest pressures, the opportunity cost of time used in delivery from farm to elevator raises the effective cost of transportation. Higher delivery cost in terms of money or time provides the geographical isolation necessary for a partial monopsony.

Transportation availability is determined largely by geography. However, the advantages of access to water can be partially offset by improved rail and truck transportation and rate structure.

The significance of factor $S_1$, which includes the price support variables, in all three models suggests a heavy influence of government support policies on the variability of prices over space. The relative inflexibility of support prices may perpetuate spatial price differentials after the market would otherwise have adjusted to changing conditions of supply and demand.

The smaller number of significant variables in model 1 is consistent with empirical observations of variability and volatility of prices during the pressures of the harvest rush. If market imperfections exist, it is likely that they would have their greatest effect during the harvesting period. Adjustment lags, inadequate information, resource immobility, and even irrational economic behavior are accentuated by the pressure of farmers trying to move grain from field to market. To the extent that on-farm conditioning and storage would produce a more uniform flow of corn to market, price variability could be decreased through an increase in farm investments in storage facilities.

Although additional analysis would be required to identify specific policy actions that would have a direct effect on performance of the corn market with respect to price variability, this study does suggest the areas in which these changes are needed and the variables that represent the malleable dimensions of the market. It also identifies the grain marketing system as a highly developed, responsive market of competing firms, operating in an industry structure characterized by monopsonistic competition and seasonally induced spatial monopsony.

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# Farm Type Classification Systems: Another Look at an Old Problem*

DON D. PRETZER AND ROBERT M. FINLEY

**Farm record classification criteria vary greatly among states. Taking a given set of records and applying the various typing criteria gave widely divergent groupings. Hence, comparison of results based on varying criteria will likely be misleading. However, dairy farms can be classified consistently with any of the methods considered.**

***Key words:*** **records; farm type; classification.**

FARM RECORD PROGRAMS in various forms have existed in many universities for many years. Segregating records into similar groupings forms a basis for studying the individual business as well as providing other useful information for extension and research. The usefulness of any program involving records depends, in a large measure, on how accurately farms are classified by type.

Methods and criteria for typing or grouping farms are not uniform among the various states. Lack of homogeneity in classification is not a great problem when comparing farms within a given state, but lack of uniformity can invalidate interstate comparisons. Thus, if interstate comparisons are to be considered, the important question must be: How comparable are various types of farms when grouped by varying criteria?

Classifying farms by type is an old problem. Almost 30 years ago Benedict *et al.* [1] pointed out that classification criteria should reflect differences in interest, characteristics, and behavior under varying conditions.

Here an attempt is made to identify and isolate various criteria used by certain North Central states to classify farms by type and to demonstrate divergences in farm typing from using various definitions and criteria.

Data chosen were a basic set of 403 records from the Missouri Mail-In Record Project for 1970. As a benchmark, the farms were first grouped by type according to the Missouri typing criteria. Each farm was then typed according to criteria used in other states. The unique criteria of each system provided new subsets or types different from the basic set of 403 records produced by the Missouri system. Thus, retyping provided the framework for evaluating any differences in types due to criteria and/or definitional differences used by other systems. The question is whether or not varying criteria result in different subsets due to criteria alone or definitional differences, although the verbal criteria appear similar. Therefore the first concern was dividing the basic set into various farm types as indicated numerically and descriptively in Table 1. Discussion will refer, for example, to general farms as Type 0 and grain farms as Type 1. While Types 1 through 9 were derived directly, Type 0 was a residual for those not meeting the requirements for Types 1–9.

The Missouri system, the benchmark, types farms according to productive man work units (PMWU), which are calculated by multiplying enterprise units (crops or livestock) times average labor factors. The enterprise PMWU's generate a percentage of the total farm PMWU's. The percentages classify farms as Type 0, 1 . . . 9.

## Results[1]

When each system of classification was applied to the basic set, "type to type" movement was dramatic. Table 1 summarizes the changes as well as the percentage in each type that did not change. Basic reasons for the changes are discussed below for each of the various classifications.

### Kansas

When Kansas criteria were applied, 176 farms changed type within this basic set. The Kansas

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[1] In the succeeding discussion only brief reference was made to the specific method of classification. If further information is desired or needed regarding specific details of classification for any system, it is suggested that these queries be directed to either author.

Table 1. Type change and percentage remaining unchanged for 403 Missouri mail-in-records farms classified by systems of indicated states and by U. S. census

| Indicated State and U. S. Census | | Farm Type, Missouri Classification | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0[a] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| | | General | Grain | Grain-Hog | Hog | Grain-Beef | Beef | Grain-Dairy | Dairy | General Livestock | Poultry | Total Farms |
| | | 100 | 78 | 39 | 29 | 31 | 21 | 0 | 99 | 4 | 2 | 403 |
| Kansas: | Enter | 0 | 55 | 39 | 34 | 19 | 1 | 22 | 1 | 5 | (0) | 176 |
| | Leave | 97 | 6 | 7 | 5 | 20 | 17 | 0 | 18 | 4 | (2) | 176 |
| | Total | 3 | 127 | 71 | 58 | 30 | 5 | 22 | 82 | 5 | (0) | 403 |
| | Remaining | 3% | 92% | 82% | 83% | 35% | 19% | 0% | 82% | 0% | 0% | 56% |
| Iowa: | Enter | 24 | 32 | ( 0)[b] | 55 | ( 0) | 24 | (0) | 4 | (0) | (0) | 139 |
| | Leave | 40 | 12 | (39) | 1 | (31) | 4 | (0) | 6 | (4) | (2) | 139 |
| | Total | 84 | 98 | ( 0) | 83 | ( 0) | 41 | (0) | 97 | (0) | (0) | 403 |
| | Remaining | 60% | 85% | 0% | 97% | 0% | 81% | 0% | 94% | 0% | 0% | 66% |
| Illinois-Kentucky: | Enter | 9 | 27 | ( 0) | 98 | ( 0) | 43 | (0) | 3 | (0) | 4 | 184 |
| | Leave | 86 | 15 | (39) | 1 | (31) | 5 | (0) | 3 | (4) | 0 | 184 |
| | Total | 23 | 90 | ( 0) | 126 | ( 0) | 59 | (0) | 99 | (0) | 6 | 403 |
| | Remaining | 14% | 81% | 0% | 97% | 0% | 76% | 0% | 97% | 0% | 100% | 54% |
| Michigan: | Enter | 162 | 1 | ( 0) | 16 | ( 0) | 34 | (0) | 0 | (0) | (0) | 213 |
| | Leave | 2 | 70 | (39) | 21 | (31) | 14 | (0) | 30 | (4) | (2) | 213 |
| | Total | 260 | 9 | ( 0) | 24 | ( 0) | 41 | (0) | 69 | (0) | (0) | 403 |
| | Remaining | 98% | 10% | 0% | 28% | 0% | 33% | 0% | 70% | 0% | 0% | 47% |
| Wisconsin: | Enter | 55 | 25 | ( 0) | 35 | ( 0) | 14 | (0) | 1 | (0) | (0) | 130 |
| | Leave | 29 | 13 | (39) | 2 | (31) | 3 | (0) | 7 | (4) | (2) | 130 |
| | Total | 126 | 90 | ( 0) | 62 | ( 0) | 32 | (0) | 93 | (0) | (0) | 403 |
| | Remaining | 71% | 83% | 0% | 93% | 0% | 36% | 0% | 93% | 0% | 0% | 68% |
| Nebraska: | Enter | 41 | 12 | ( 0) | 54 | ( 0) | 25 | (0) | 2 | (0) | (0) | 134 |
| | Leave | 35 | 18 | (39) | 0 | (31) | 2 | (0) | 3 | (4) | (2) | 134 |
| | Total | 106 | 72 | ( 0) | 83 | ( 0) | 44 | (0) | 98 | (0) | (0) | 403 |
| | Remaining | 65% | 77% | 0% | 100% | 0% | 90% | 0% | 97% | 0% | 0% | 67% |
| U. S. Census: | Enter | 0 | 20 | ( 0) | 0 | ( 0) | 0 | (0) | 3 | 223 | 1 | 247 |
| | Leave | 100 | 22 | (39) | 29 | (31) | 21 | (0) | 4 | 0 | 1 | 247 |
| | Total | 0 | 76 | ( 0) | 0 | ( 0) | 0 | (0) | 98 | 227 | 2 | 403 |
| | Remaining | 0% | 72% | 0% | 0% | 0% | 0% | 0% | 96% | 100% | 50% | 39% |

[a] Type 0 is for farms that do not meet criteria for other types.
[b] Parentheses ( ) indicate types not classified by system indicated.

and Missouri systems are similar in that verbal criteria (i.e., productive man work units) are the same. Basically, the major reason why almost half the farms changed classification can be attributed to two causes. The first was that each state uses a different factor to multiply by acres or animal units to arrive at a productive man work unit.[2] The second is that the percentages used to segregate individual farms into types are different.[3] A major result of relaxing percentage requirements from Missouri to Kansas was a movement of farms into specific types such as grain, hogs, beef, and dairy, and the exit of general farms. The largest exit was from Type 0, general farms; all but three left that classification.

Dairy farms (Type 7) were thought to exhibit the most stability, and this expectation was fulfilled as 82 percent of the farms typed by the Missouri system remained as dairy farms under the Kansas criteria. However, even here, considerable turnover occurred with one farm entering but 18 farms leaving by the Kansas criteria. All 18 exits went into a more general classification of the grain-dairy farms, Type 6. Changes in dairy farm classification can be explained primarily by the differences in the factor used to calculate productive man work units. A much higher factor is used in Missouri than in Kansas. The implications at this point are not to suggest that either classification system is necessarily correct (or incorrect), but they do suggest a need for empirical data, particularly of the time and motion type, to validate factors used to define productive man work units. Each typing system uses somewhat arbi-

[2] For example, for dairy, Missouri used 10 days for each mature cow plus 1.5 days for other dairy stock while Kansas used 9 days per head of mature cows.

[3] For example, requirements to be typed as a grain farm in Missouri were: (a) less than 33 percent of the total PMWU's used for any one animal enterprise and (b) 50 percent or more of the total PMWU's used in crop production.

To be typed as a grain farm in Kansas, requirements were: (a) 33⅓ percent or more of the total PMWU used for crop production, (b) 33⅓ percent or less of the total PMWU's in dairy enterprises, (c) 33⅓ percent or less of the total PMWU's for hog production, and (d) 33⅓ percent or less of the total PMWU's for beef production.

trary percentages whose rigidity may be limited by the number of farms in each state's basic set (i.e., a state with large numbers of farms in their program may want more rigid requirements for farm typing than a state with few farms in the program).[4]

## Iowa

The Iowa system differs in both structure and method from either the Missouri or Kansas systems. However, classifying of the basic set by the Iowa system caused only 139 farms to change type (Table 1). Iowa's system initially separated grain farms from other farms in the basic set. The grain farms, Type 1, were those which had sales greater than one-half the value of feed produced. Use of the Iowa system on the 403 Missouri farms resulted in the exit of 12 farms from the general farm classification; but 32 farms with some livestock type designation (e.g., grain-hog or grain-beef) entered as grain farms.[5] If types indicating livestock combinations had been used (e.g., beef-hog or dairy-beef), fewer farms likely would have been classed as general (Type 0). The 100 farms typed as general with the Missouri system fell to 84 with the Iowa system with 40 exits and 24 entries. Thus, 60 percent of the original type remained.

Again, the dairy farm classification was quite stable with a net change of only two. Large differences, however, occurred in the numbers entering hog and beef farms. Each required a ratio greater than .7 for value of the specific livestock production to the value of all livestock production to be classified as a hog or beef farm.[6]

## Illinois and Kentucky

The initial criteria for typing farms under the Illinois and Kentucky systems were similar to the Iowa system. The first division classified as grain farms those where the value of feed fed to the feed and grain returns from the farm was less than one-half and the value of feed fed to poultry or dairy was less than one-sixth of the feed and grain returns. Some farms classified as dairy or poultry farms would have been classified as grain farms under the Iowa and, perhaps, the Missouri systems.

The dairy type again showed great stability—only three farms leaving and three farms entering with Illinois-Kentucky criteria applied to Missouri farms. Grain farms and general farms accounted for most of the exits. However, considerable changes occurred in entries due to not considering all original ten classifications. Most of the changes were in the hog farm entries—from the grain, grain-hog, and general farm classifications. Entries in grain and in beef types were primarily from Missouri's general and grain-beef classifications.

The feed-fed criteria of Illinois-Kentucky caused 184 farms to change type and demonstrated instability second only to Michigan's specialized farm criteria. Some of the differences between the Missouri system and the Illinois-Kentucky system could result from price variations in the feed input. The physical feed fed input should be rather stable from year to year on average farms, but the price of the feed could vary and cause instability in inter-yearly classifications.

## Michigan

The Michigan system classifies farms by type using "value of production." Total value of production is calculated as follows: total gross value of farm production minus the cost of purchased feed and livestock. Here the basic notion is to generate ratios for the value of individual farm enterprise production to the value of total farm production to accomplish the typing. The system illustrates use of rather rigid percentage requirements for classification. Because the Michigan system has a large number of records, rigid classification may be more feasible than for states with fewer records.

As with the other systems, the initial break was with the grain farms; however, to be typed as a grain farm, the ratio of crop value to value of farm production had to be greater than .95; hence, as would be expected, the number of

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[4] Nonetheless, it should be pointed out that this policy has not been followed by Kansas and Missouri; Missouri used more rigid requirements to classify several hundred records than does Kansas which classifies several thousand records.

[5] The grain-livestock types (2, 4, and 6) and the mixed livestock type (8) were not included in the Iowa system, so the two systems were not directly comparable for those four types.

[6] Comparison of these two systems of classification suggests a real need to study the relationship between value of production and the man-work units required to produce specific levels of outputs for specific types. Part of the variation in composition of Types 3 and 5 could be explained by variation in 1970 livestock prices. The assumption is sometimes made that the work units are a proxy for all other inputs. When this assumption is not correct, then either the criterion, productive man work units, is not an appropriate carrier or proxy for other inputs or value of production is not correctly indicated.

grain farms was greatly reduced when this criterion was applied. Dairy farms showed some stability; 70 percent typed by the Missouri system remained dairy farms under Michigan criteria. All dairy exits became general farms. With several Missouri classifications not included in the Michigan system and a rigid type of classification, general farms increased greatly. Beef farms increased primarily because many grain and grain-beef farms were classified as beef farms when the value added by grain fed to livestock increased the ratio.

### Wisconsin

Wisconsin's typing system uses value of production criteria; however, value of production is computed quite differently as compared to Michigan. Value of farm production by the Wisconsin system is value of livestock production plus value of crop produced but adjusted by subtracting the value of home-grown feed fed.[7] The method used to determine a specific type was an initial separation of grain farms from other farms. After certain specific livestock farms were determined, all other farms were assumed to be general farms (Type 0).

As shown in Table 1, again dairy farms did not change greatly from the initial comparison, but certain types, including general farms, increased. Changes were caused partly because certain grain-livestock and livestock-livestock classifications were not included but perhaps, more importantly is the observation that other farm types were recipients of these farms as well as the residual category, general farms.

### Nebraska

Nebraska is still another system where the analysis was made on a notion of value of production. The Nebraska system uses a concept of gross production; gross production is an estimate of all value added on the farm during the year. Hence, it is total net livestock production plus total value of all crop production. Net livestock production is the value added to all classes of livestock during the year and accounts for purchases, sales, inventory change, and home use. Thus, net livestock production can be said to be accounted for on an accrual basis. The other component of gross production is total value of all crop production. Gross production as thus calculated is an inflated production figure and is functionally related to the amount of feed fed to livestock. For example, if all crop production were fed to livestock, value is counted twice in arriving at the gross production. That is, the total value of all crop production is added to the value of livestock production and thus is accounted for in net livestock production, as well as accounted for in the crop production. Use of the Nebraska system produced groupings similar to those by the Michigan system. Again, except for dairy farms a low percentage of the farms in specific types remained unchanged from the original or benchmark types.

Conclusions concerning this system are similar to some of those previously noted. All effects of the system's double counting or crop production cannot be isolated here. However, the ratios for grain farms should be smaller due to the large denominator. The ratios calculated for typing pure livestock farms will vary according to the magnitude of the constant (value of crop production) added to both the numerator and the denominator.

### Census

U. S. census classifications are included because of their wide and general usage. Census data often can be used to compare or expand upon record results where a broader description is deemed necessary. The census determines farm types by income. Income is cash or expected sales. The census adjusts for government payments and sales of capital items.[8] The census system divides farms into grain systems and other farms similar to those discussed (i.e., grain farms are those where crop sales are greater than one-half of adjusted farm sales). The census system resulted in several farms shifting from the original classification. Not all farms typed by the original set were included in the census system so that only grain, dairy, poultry, mixed livestock, and general farms were typed. The general livestock class (Type 8) included all of the specialized livestock farms except dairy farms. None of the 403 Missouri farms went into the general farm classification of the census. Ninety of the 100 farms classed as general farms by the Missouri system moved into the mixed livestock class. Dairy again was highly stable; 96 percent of the dairy type farms were classified the same by the census system.

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[7] The Michigan adjustment was made by subtracting the cost of purchased feed and livestock.

[8] Sales of capital items are also eliminated from many systems discussed, but government payments are usually included as part of the gross income or sales.

## Summary

The various systems of classification did not give a consistent pattern of typing when applied to the basic set of farm records. Further, even when classification systems appear to be the same or at least similar, results in typing were often widely divergent. Therefore, the conclusions must be that the comparison (or even worse, the combining) of results from record programs from various states can be, at least, misleading and is not a practice to be recommended or condoned. The record systems as now constructed may fit needs in individual states but are often highly provincial and will remain so until and unless, typing criteria are standardized. If record data involving several states are to be used, one should consider utilizing the data in a "raw" form and not as groupings based on varying criteria. Attention needs to be given to eliminating differences arising from interyearly (and interregional) differences in value of production and of inputs used. Characteristics inherent with dairy farms permit them to be classified consistently by various systems now used.

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# Market Liquidity in the FCOJ Futures Market

RONALD W. WARD

**Speculation is essential for maintaining liquidity within futures markets. Deviations in speculative trading about a liquidity level may, however, distort market price performance. The liquidity level for FCOJ futures has been derived. Speculation in excess of liquidity occurred infrequently and such excesses showed only limited effects on price performance.**

***Key words:*** **futures market; excess speculation; price distortion; orange concentrate.**

FUTURES TRADING in FCOJ (frozen concentrated orange juice) represents a major innovation to the processed foods sector [5, 7]. The vitality and success of this market, as with all futures, depends on an adequate trading volume by industry and speculative traders to facilitate establishing futures positions without realizing a cost from market entry or exit. The composition of the open interest (hedging or speculation) gives a measure of the use being made of the market by various trader types.

Hedgers enter the market to complement their cash market activities, while the speculative trader establishes futures positions in expectation of futures price movements [8]. Speculative trading is essential for the proper execution of hedging activities. If a trade cannot be easily executed at any point in time, then the risk from futures trading is greatly increased. The speculative trader provides the necessary level of trading activity or "liquidity" to the market to prevent the occurrence of added risk from failure to establish or terminate a contract. Hence, "market liquidity" or the necessary level of speculation relative to hedging positions represents a crucial element to the overall performance of a futures market.

Speculation provides liquidity to the futures market; yet speculation far in excess of liquidity needs may distort its price performance. The concepts of liquidity and excess speculation have been addressed in the literature; however, few empirical measures of either have been made. Likewise, attempts to measure any distortion resulting from excess speculation have been sparse. Gray [3] explored the price effects of speculation in commodity futures and concluded that ". . . with ample speculation there is no price effect, whereas the price effect of speculative deficiency is substantial." Working [9] discussed in detail the role of speculation in futures trading. He developed a speculative index from which a similar index was designed in this paper. However, in his study of the wheat futures he did not quantify the level of his index that was considered necessary to provide the protective margin or "liquidity" to the wheat market.

Both Working [9] and Gray [3] used the reported and non-reported data from the Commodity Exchange Authority (CEA). Gray assumed all non-reported data to be speculative while Working developed "hedging" and "speculative" ratio rules for using non-reported data. Larson [4] addressed the problem of non-reported futures positions and provided an estimating procedure for dealing with the non-reported data as published by the CEA. He emphasized the need for improved reporting systems. These articles have served to help clarify the role of speculators; however, none of them completely provides a quantitative measure of market liquidity nor a measure of price distortion when deviations about liquidity occur.

Two major factors have hindered the measurement of excess speculation and its effects on price performance. First, the lack of complete identification of the composition of open interest for most contracts prevents a true measure of excess speculation. For example, the Commodity Exchange Authority reports the composition of large traders; however, the intent of small traders is not identifiable [6]. Frequently, a major portion of the open interest is held by small traders. Second, few data series exist that are useful for relating market price performance to the concept of market liquidity.

A measure of excess speculation and its effects is extremely critical when evaluating and setting policies relating to the conduct of a futures market. If a market consistently demonstrates a high level of excess speculation and if this can be shown to have detrimental effects on price performance, then policy adjustments relating to the structure of a specific futures market may be needed. Such adjustments include new contract definition, revised trading limits, improved re-

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porting systems, and changes in margin requirements.

Both the concept and measurement of excess speculation and its effect on price performance as it relates, specifically, to the frozen concentrated orange juice futures market will be addressed in this paper. Alternative data sources to that of the CEA are used. In the first section a "speculative index" used to measure excess speculation is derived and related to FCOJ futures trading. A measure of FCOJ futures price performance is then related to the speculative index. Finally, the general policy implications are discussed.

## Speculative Index *i*

Excessive speculation is defined to be that amount of long (purchased contracts outstanding) or short (sold contracts outstanding) speculation over what is needed to satisfy net hedging transactions and market liquidity.[1] This excess is measured via a "speculative index" where the index measures the absolute level of speculation relative to what the hedging market would suggest as adequate for market liquidity; i.e., if hedging is net short (long), then speculative buying (selling) is necessary to complete the transactions [9].

The index is defined as:

$$(1) \quad i = \begin{cases} S_l[H_s - H_l]^{-1}, & \text{if } (H_s \geqq H_l) \\ S_s[H_l - H_s]^{-1}, & \text{if } (H_l > H_s) \end{cases}$$

$$i \geqq 1$$

where

$H_s =$ short hedge (all trading variables measured in contract units outstanding),

$H_l =$ long hedging,

$S_s =$ short speculation,

$S_l =$ long speculation.

All index values of equation (1) must be equal to or greater than one plus a liquidity factor. The lower limit to $i$ follows since there must always be enough speculative commitments at least to offset the net hedged positions and assure market liquidity. Suppose the index were 1.75, then speculation would be 75 percent over the minimum to offset the net hedged position. Index values greater than a necessary liquidity level (to be estimated subsequently) suggest excessive speculation. Index measures greater than that necessary for market liquidity indicate that groups of speculators are interpreting the same information differently or are utilizing market information totally ignored by other speculative groups.

The speculative index for FCOJ was directly measured from the hedging and speculative weekly data reported by the Citrus Associates of New York [1]. These data give a detailed account of all traders irrespective of the size of their futures commitment over the weekly intervals from January 1971 through May 1973.[2]

Applying the Citrus Associates' weekly data to equation (1) reveals the pattern of speculative commitments in FCOJ. The index ranged from a low of 1.681 to a high of 322.00 with a mean value of 14.994. The extreme upper ranges of the index resulted in part from periods when short and long hedged commitments were nearly equal. However, this occurred only seven times out of 115 observations. Both the range and mean indicate that speculation in excess of hedging needs has occurred; however, a frequency distribution of the index shows the speculative trading not to be as excessive as suggested by the upper range of $i$.

A probability density function of the FCOJ index is shown in Figure 1. Approximately 60.0 percent of the $i$'s were in the range of 5.0 or less while less than 16 percent of all $i$'s exceeded the mean value. The departure of the distribution from normality is further quantified by the degree of skewness ($k_1 = 5.82$). The distribution is leptokurtic with a kurtosis ($k_2$) of 36.39. These statistics give a good measure of the tendency for excess speculation. The larger the value of $k_1$ the greater the accumulation of speculative index values in the lower range of the index scale. Increases in $k_2$ indicate a concentration about a given index value or a peaked-

[1] This definition places the speculators in the position of providing that level of trading necessary for maintaining a liquid market. The definition is based on the argument that the main function of the futures market is to facilitate hedging activities and that speculative trading is necessary to facilitate this function.

[2] Both the total number of outstanding long and short contracts held by all speculators and by all hedgers are reported on a weekly basis. All contract spreads are included in the total number of speculative contracts. These data differ from that reported by the Commodity Exchange Authority in that it is weekly rather than bi-monthly and all open interest is identified as hedging or speculation whereas the CEA identifies the larger traders only. Larger traders in FCOJ are those with 25 or more outstanding contracts at any point in time [1, 6].

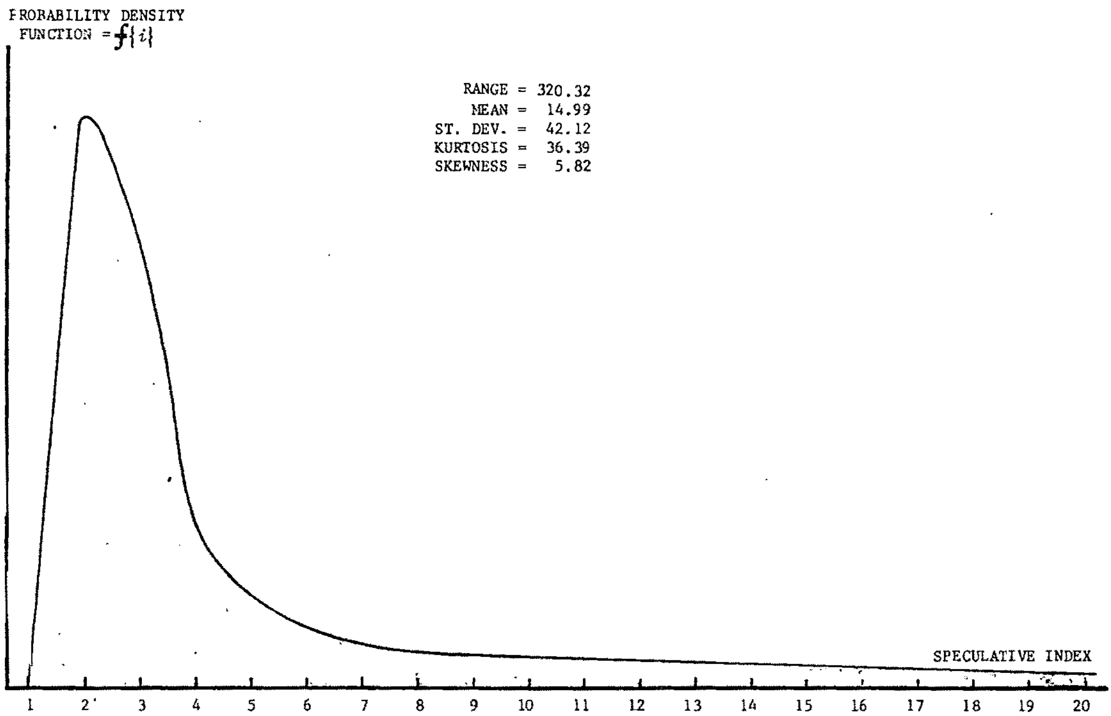


**Figure 1. The probability density function for the FCOJ speculative index**

ness in the distribution. Monitoring both $k_1$ and $k_2$ over time provides a simple method for quantifying any changes toward excessive speculation.

## Price Effect from $i$

The distribution of $i$ in Figure 1 indicates that the FCOJ futures has not been dominated by levels of excessive speculation. The mode of values is in the lower range of the index scale. However, levels of speculation in excess of hedging needs are evident. A knowledge of the price effects of such excesses is essential for directing new structural policies for the FCOJ market. To measure any price effect, it is first necessary to outline briefly the industry's pricing system.

Two price series exist for measuring the value of oranges used for processing. First, approximately 80 percent of the oranges are sold under contract agreement where the DELIVERED-IN price received by the grower is derived from the average FOB price after the season is complete. The FOB price tends to be rigid and hence does not reflect many of the minor market adjustments and expectations. The remaining 20 percent of the oranges used for processing are sold in the cash market at the SPOT DELIVERED-IN price [2]. This price changes continuously in accordance with present crop and market conditions and expectations about future conditions. The spot price will generally be discounted relative to the equivalent delivered-in price derived from the FOB price when inventories are accumulating faster than desired. Likewise, the spot price may be at a premium when inventories are below the desired level. The FCOJ NEAR FUTURES price and the SPOT price react to market information and expectations in similar manners as evident from a high correlation coefficient between these prices ($\rho = .8891$). However, the futures price should be above the spot price by the cost of converting delivered-in pounds solids to bulk juice in the barrel. The delivered-in pounds solids is quoted in 45° brix while bulk juice and futures contract are in 58° to 65° brix. Brix value is the degree of acidity found within the juice.

Both the spot and futures prices are influenced by traders simultaneously involved in cash and futures trading. In addition, the futures market is influenced by the speculator's interpretation of market information. Deviation in the price spread between the futures and spot markets can be related to speculative positions via the speculative index. A measure of the relationship between

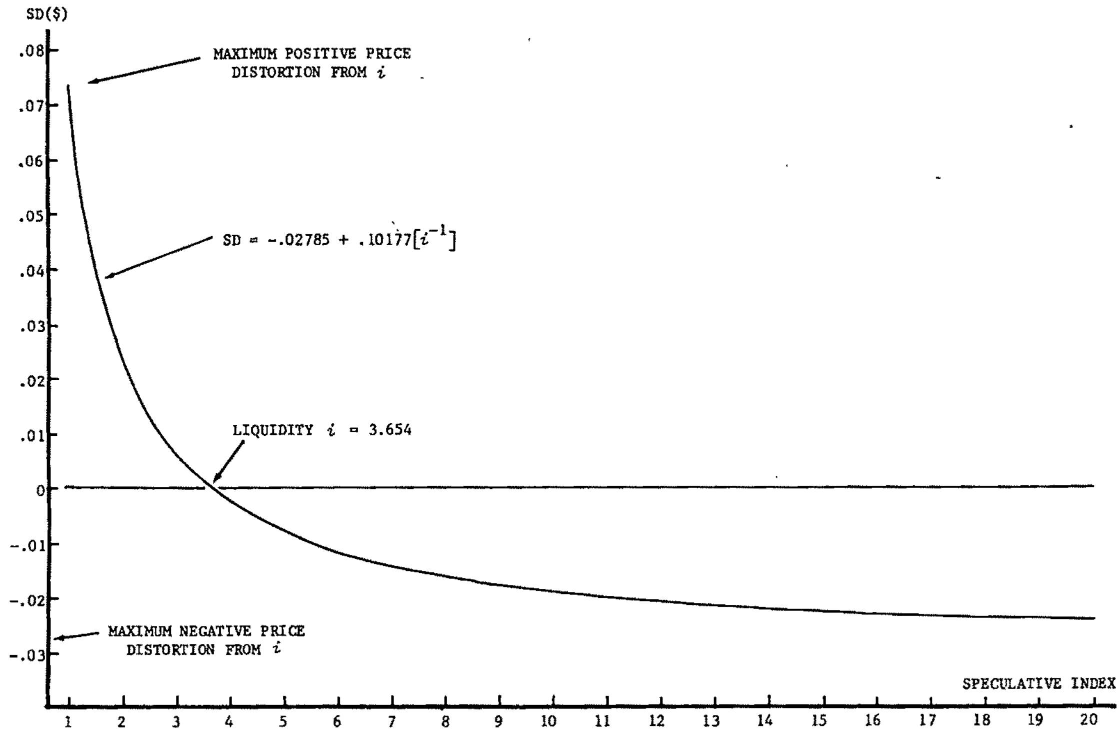


**Figure 2. The relationship between FCOJ futures and spot price distortion and the FCOJ speculative index**

the spread ($SD$) and $i$ gives some indication of price distortion that may result from excessive speculation.

Define:[3]

$SD$ = NEAR FUTURES − SPOT − COST

where

COST = approximate cost per pound solids for production of bulk juice and putting juice in the barrel,

NEAR FUTURES = near futures price per pound solids of bulk FCOJ (58° to 65° brix) [1],

SPOT = spot price per pound solids of FCOJ delivered-in (45° brix) [2].

The estimated relationship between the price spread and the speculative index was[4]

$$(2) \quad SD = -.02785 + .10177[i^{-1}] \quad (t = 4.71373)$$

$$R^2 = .2072,$$

$$n = 86.$$

The results of equation (2) show a significant effect of speculative pressure on the FCOJ price spread. For this market, increases in $i$ lead to decreases in the spread as shown in Figure 2. *A priori,* the sign of the marginal effect of $i$

[3] The cost of processing and containerizing bulk juice varies across processors. The industry average cost may not be exactly paralleled in the price spread if the more efficient processors tend to use the futures market. Estimates of the industry bulk product costs have ranged from .06 to .13 dollars, while the average price spread equals .071 dollars. Rather than using a value within the range of industry estimates, the average spread $(\overline{SD})$ has been used as an estimate of COST. This average is in the lower range of the industry estimates and may be reflecting futures trading by the more efficient processors.

The SPOT price does not exist from early August to late October since all oranges for processing have been harvested and delivered in to the processors. Hence $SD$ was derived excluding these months from the series of data.

[4] Both linear and quadratic estimates were compared to equation (2) giving the following.

| | | |
|---|---|---|
| Linear | $R^2 = .058$ | $F = 5.347$ |
| Quadratic | $R^2 = .096$ | $F = 4.509$ |
| Reciprocal | $R^2 = .207$ | $F = 22.214$ |

*A priori,* the amount of price distortion was expected to be within a given range since the maximum daily fluctuation in futures is limited. The reciprocal function includes upper and lower limits to the distortion whereas the other two functions do not.

is not clear since $i$ includes both speculative buying and selling. However, over 63 percent of the $i$'s used in the analysis resulted by speculative selling, and this may have contributed to the negative effect of the index.[5]

Equation (2) provides a quantitative measure of the "liquidity level" and the price distortion resulting from index values in excess of the liquidity level. $SD = 0$ when the market prices are reflecting the normal price spread. Solving equation (2) for $SD = 0$ gives "liquidity" $i = 3.654$. Hence, speculative positions yielding index values larger than 3.65 can be considered in excess of that necessary for attaining the normal price performance in the FCOJ futures market relative to the cash market.

[5] Recognizing that the effects of the index could vary according to whether the speculative pressure resulted from long versus short positions, equation (2) was re-estimated using dummy variables to distinguish between the $i$ values derived in equation (1). Let

$$SD = \gamma_0 + \gamma_1 D_2 + \gamma_2[D_1 i^{-1}] + \gamma_3[D_2 i^{-1}]$$

where

$$D_1 = \begin{cases} 0 & \text{if } H_s \geqslant H_l \\ 1 & \text{if } H_l > H_s \end{cases}$$

$$D_2 = \begin{cases} 1 & \text{if } H_s \geqslant H_l \\ 0 & \text{if } H_l > H_s. \end{cases}$$

The resulting estimate follows where

$$SD = -.02751 - .00071 D_2 + .09775[D_1 i^{-1}] + .10920[D_2 i^{-1}]$$
$$(t = .005) \quad (t = 3.388) \quad (t = 3.194)$$

$R^2 = .20838.$

Note that the signs and magnitudes of $\gamma_2$ and $\gamma_3$ are nearly equal. Thus the effects of the index are influenced little by the nature of the speculative pressure used in defining $i$. Likewise, $\gamma_1$ is insignificant and $\gamma_0$ differed little from .02785 derived in equation (2).

The maximum distortion from speculation in excess of liquidity also follows from equation (2). Note that

$$\lim_{i\to\infty} SD = -.02785.$$

Therefore, large index values will distort the normal price spread by no more than $-.02785$ dollars. This maximum distortion is relatively small when compared to the range of $SD$ found within the data; i.e., $-.077 \leqq SD \leqq .095$. The speculative index accounted for only about 20.7 percent of the total price distortion.

Index values less than the liquidity level reveal a positive price distortion. If speculative trading just offset the hedging needs (i.e., $i = 1$), then the relationship of (2) suggests a price distortion in the range of seven cents. Thus, the conclusions following from these estimates show that a greater potential price distortion results from lack of market liquidity rather than values in excess of liquidity. Also, as shown in Figure 1, the probability of insufficient speculation is much larger than that of excessive speculation.

## Conclusion

From a historical perspective, many public policies related to futures trading are based on evidence indicating excess speculation and resulting detrimental effects. In this respect, FCOJ futures have been and will be continually scrutinized as to the behavior and performance of the market. The speculative index and its relationship to price distortion provide a clear signaling mechanism to alert policy makers of any needed structural changes in this futures market. Likewise, the methodology reveals the need for improvements in the present system for monitoring futures commitments in general.

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# *Communications*

## AMERICAN AGRICULTURE AND THE PROPHECY OF INCREASING MISERY: COMMENT

It would be reassuring if we did not have to be reminded of such basics as correct usage of data, adequate knowledge of existing data systems, selection of the proper series from such systems, and coherence between the objective of a project and the data used. However, a recent article in this journal written by Lianos and Paris [2] violates all of these fundamental considerations of proper research procedure. These are rather serious charges, but each will be substantiated in this paper.

I present the components of the basic data series used in this article, their sources and content, and four additional years of data in Table 1.

To review Lianos and Paris' computation procedures briefly, we note that in a Marxian conceptual framework the value of total output is the sum of three components: constant capital ($c$), variable capital ($v$), and surplus-value ($s$). The relative income share of labor is defined as $S'_L = v/(v+s)$, and the relative income share of capital is defined as $S_K = s/(v+s)$. By dividing $S_K$ *by* $S'_L$, we obtain the rate of exploitation, $s/v$. Lianos and Paris use the U. S. farm income accounts for their basic output data base, thus 48-State data for 1949–1959 and 50-State data for 1960–68. The composition of total output and constant capital are listed in the footnotes to Table 1. The estimate of the value of total output is deflated by the index of prices received by farmers (1957–59 = 100). The constant capital estimates are deflated by the index of prices paid by farmers for all commodities bought including interest, taxes, and wage rates (1957–59 = 100). The difference between deflated total output and constant capital is used as their deflated estimate of the sum of variable capital and surplus-value ($v + s$) which is the denominator of their labor and capital share equations. Their estimate of variable capital ($v$) or wage bill is computed as the product of the total man-hours used for farm work in the 48 contiguous State and the deflated composite farm wage rate per hour.[1] The wage rate is deflated by the same index of prices paid as the constant capital series. This provides all the data needed for their computations, and they estimate $S'_L = v/(v+s)$; $S_K = 1 - S'_L$; rate of exploitation $= S_K/S'_L$; and organic composition of capital $= c/v$.

Using these computation procedures, the reader will be able to reproduce Lianos and Paris' estimate of $S'_L \pm .01$ for most years, but not their estimate of the organic composition of capital.

### Correct Use of Data

A comparison of Lianos and Paris' deflated wage rate (Table 2, col. 1) with the actual composite farm wage rate in Table 1 makes the first error apparent. They contend they have deflated all series to 1957–59 dollars. But in fact, their labor share is expressed in something like 1967 or 1968 dollars and their surplus-value plus variable capital estimates in 1957–59 dollars. The effect of using these different bases can be seen by comparing columns 3 and 4 of Table 3. Column 3 is copied from their Table 2 with the exception of the 1949 estimate for which a computational error was corrected. Use of consistent base periods does not appreciably affect the basic trends Lianos and Paris noted. It does eliminate the necessity of rationalizing a negative rate of exploitation and implies an even greater rate of exploitation during recent years than they had estimated.

As previously stated, I was unable to reproduce their estimates of the organic composition of capital. The two series are presented in columns 1 and 2 of Table 3. The fact that Lianos and Paris' series nearly converges with mine around 1968 in a pattern similar to their deflated wage rate series compared with the actual wage rate series suggests some of the difference may be explained by inconsistent base periods. However, it can be shown that the constant capital estimate implicit in making their labor share estimate differs from that used in making their organic composition of capital estimate ($R$), e.g., 1957 from the formulas and from Lianos and Paris' Table 2, $S'_L = .702$, $v = 9931$, and $R = 1.69$, and Table 1 of this note, deflated output = 31,816 ÷ .97 or 32,800.

$$Q = c + s + v;\ S'_L = \frac{v}{Q - c},\ \text{and}\ R = c/v$$

$$c = \frac{S'_L\, Q - v}{S'_L}\ \text{and}\ c = R \cdot v$$

The $c$ implicit in the labor share estimates is 18,654

[1] The composite farm wage rate is also based on 48-State data. For consistency of data series, the 1960–68 output and constant capital estimates should be calculated using 48-State data from [5]. To keep my data series comparable to that of Lianos and Paris, this change was not made, so my rate of exploitation estimates for this period has a slight upward bias.

Table 1. Statistical series employed in Lianos-Paris article, 1949–72

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Year | Prices received index[a] 1957–59 = 100 | Prices paid index production items[a] 1957–59 = 100 | Prices paid index all items[a] 1957–59 = 100 | Composite farm wage rate[b] ($) | Employment[c] (Million Manhours) | Output[d] (Mil. $) | Constant capital[e] (Mil. $) |
| 1949 | 103 | 91 | 86 | .559 | 16,202 | 29,169 | 13,197 |
| 1950 | 107 | 94 | 87 | .561 | 15,137 | 31,336 | 14,447 |
| 1951 | 125 | 104 | 96 | .625 | 15,222 | 36,346 | 16,980 |
| 1952 | 119 | 104 | 98 | .661 | 14,504 | 35,670 | 17,319 |
| 1953 | 105 | 97 | 95 | .672 | 13,966 | 32,385 | 16,265 |
| 1954 | 102 | 97 | 95 | .661 | 13,310 | 32,112 | 16,738 |
| 1955 | 96 | 96 | 94 | .675 | 12,808 | 31,383 | 17,076 |
| 1956 | 95 | 95 | 95 | .705 | 12,028 | 31,530 | 17,446 |
| 1957 | 97 | 98 | 98 | .728 | 11,059 | 31,816 | 18,289 |
| 1958 | 104 | 100 | 100 | .757 | 10,548 | 35,786 | 19,927 |
| 1959 | 99 | 102 | 102 | .798 | 10,301 | 34,921 | 20,812 |
| 1960 | 98 | 101 | 102 | .818 | 9,795 | 35,747 | 20,917 |
| 1961 | 99 | 101 | 103 | .834 | 9,400 | 36,606 | 21,442 |
| 1962 | 101 | 103 | 105 | .856 | 8,979 | 38,028 | 22,862 |
| 1963 | 100 | 104 | 107 | .880 | 8,664 | 39,037 | 23,742 |
| 1964 | 98 | 103 | 107 | .904 | 8,194 | 37,343 | 23,512 |
| 1965 | 103 | 105 | 110 | .951 | 7,775 | 41,157 | 24,813 |
| 1966 | 110 | 108 | 114 | 1.030 | 7,381 | 44,030 | 26,967 |
| 1967 | 105 | 109 | 117 | 1.120 | 7,269 | 44,097 | 28,317 |
| 1968 | 108 | 111 | 121 | 1.210 | 7,005 | 44,986 | 29,340 |
| 1969 | 114 | 116 | 127 | 1.330 | 6,695 | 48,958 | 31,431 |
| 1970 | 116 | 120 | 134 | 1.42 | 6,522 | 51,319 | 33,131 |
| 1971 | 118 | 125 | 140 | 1.48 | 6,398 | 55,214 | 36,340 |
| 1972 | 132 | 133 | 148 | 1.58 | 6,172 | 62,119 | 40,392 |

[a] Compiled by Statistical Services Group, Sector Performance Measures, National Economic Analysis Division, ERS, from [6].
[b] Compiled by Statistical Services Group from [7].
[c] [4, p. 25, and 3, 1972 issue, Table 689, p. 568].
[d] Cash receipts from farm marketings, value of farm products consumed directly in farm households, and net change in farm inventories [5].
[e] Feed, seed, livestock, fertilizer and lime, repair and operation of farm capital items, depreciation, interest, and miscellaneous farm expenses [5].

and for the organic composition of capital estimate is 16,783.

## Knowledge of Existing Data Systems

A second fundamental element of good research procedure is to be aware of the various data series relevant to one's problem and the choice of the proper data series from among alternative data series. For the information of Lianos and Paris, a continuing series on value added in agriculture is published by the U.S. Department of Commerce [8]. This estimate is based primarily on farm income numbers estimated in the USDA with only minor adjustments made in the Dapartment of Commerce to maintain consistency within the National Income and Product accounts. Using gross farm product instead of their concept of value added would not greatly affect their observation of a declining share of value added going to labor, but the context of their article does not appear to require a special definition of value added in agriculture. Their definition has at least one conceptual inconsistency. (Their exclusion of expenses for purchased livestock from intermediate products consumed introduces double counting of feeder livestock into value added).

Lianos and Paris chose the index of prices paid by farmers for all commodities including interest, taxes, and wage rate to deflate their constant capital series. *Agricultural Statistics,* where they apparently obtained this index, publishes an index of prices paid by farmers for all production items. While neither series exactly matches the mix of items they wanted to deflate, his second series is closer than the series they chose, which includes commodities used for family maintenance, interest, taxes, and wages in

Table 2. Lianos-Paris data corrected with consistent base years for deflators and with comparisons with uncorrected wage rate, 1949–1972

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Year | Lianos-Paris deflated wage rate ($) | Wage rate correctly deflated ($) | Wage bill (Mil. $) | Surplus plus variable capital (Mil. $) | $S'_L$ | $S_K = 1 - S'_L$ |
| 1949 | .791 | .650 | 10,531 | 12,974 | .812 | .188 |
| 1950 | .784 | .645 | 9,763 | 12,680 | .770 | .230 |
| 1951 | .794 | .651 | 9,910 | 11,389 | .870 | .130 |
| 1952 | .826 | .674 | 9,776 | 12,303 | .795 | .205 |
| 1953 | .863 | .707 | 9,874 | 13,722 | .720 | .280 |
| 1954 | .853 | .696 | 9,264 | 13,863 | .668 | .332 |
| 1955 | .872 | .718 | 9,196 | 14,525 | .633 | .367 |
| 1956 | .905 | .742 | 8,925 | 14,825 | .602 | .398 |
| 1957 | .898 | .743 | 8,217 | 14,138 | .581 | .419 |
| 1958 | .920 | .757 | 7,985 | 14,483 | .551 | .449 |
| 1959 | .931 | .782 | 8,055 | 14,870 | .542 | .458 |
| 1960 | .951 | .802 | 7,856 | 15,601 | .504 | .496 |
| 1961 | .961 | .810 | 7,614 | 16,159 | .471 | .529 |
| 1962 | .962 | .815 | 7,318 | 15,878 | .461 | .539 |
| 1963 | .981 | .822 | 7,122 | 16,848 | .423 | .577 |
| 1964 | 1.001 | .845 | 6,924 | 16,131 | .429 | .571 |
| 1965 | 1.036 | .865 | 6,725 | 17,401 | .386 | .614 |
| 1966 | 1.079 | .904 | 6,672 | 16,372 | .408 | .592 |
| 1967 | 1.146 | .957 | 6,956 | 17,794 | .391 | .609 |
| 1968 | 1.190 | 1.000 | 7,005 | 17,406 | .402 | .598 |
| 1969 | — | 1.047 | 7,010 | 18,197 | .385 | .615 |
| 1970 | — | 1.060 | 6,913 | 19,516 | .354 | .646 |
| 1971 | — | 1.057 | 6,763 | 20,835 | .325 | .675 |
| 1972 | — | 1.068 | 6,592 | 19,768 | .333 | .667 |

Sources: Col. 1 is from [2, p. 574, Table 2, col. 1]. Col. 2 is the quotient of col. 4, Table 1 ÷ col. 3, Table 1. Col. 3 is the product of col. 2, this table, and col. 5, Table 1. Col. 4 is (col. 6, Table 1 ÷ col. 1, Table 1) — (col. 7, Table 1 ÷ col. 3, Table 1). Col. 5 is col. 3 ÷ col. 4. Col. 6 is 1 — col. 5.

addition to the production items. As illustrated by Table 3, the choice of the prices paid index used for deflation influences the results of their analysis. They note an increase in the rate of exploitation of 7.7 times during the 1949–68 period (column 3). By correcting computation errors, this was corrected to 6.4 times in column 4 of Table 3, and by using a more appropriate deflator of constant capital, this increase is reduced to 2.6 times (column 5). This rate went up 1.3 times between 1968 and 1972 with both methods of deflation.

## Coherence Between Data and the Rest of the Research Procedure

Lianos and Paris' apparent disregard for the role of data in economic research is further evidenced by their inconsistent definitions of surplus value. On page 572 they state "the surplus-value was estimated by subtracting from total agricultural output all production expenses except net rent to nonfarm landlords. The difference consists of rent and profits." On page 573 they state "the surplus-value is the difference between the value of gross product and the value of capital (constant as well as variable) entered in the production of that product: it thus consists of profits, interests, and rents." The reader may think that one of these is a mere proofreading error and the implicit definition in the data will provide the correct answer. Examining the implicit definition in the computational procedure confirms neither of the above definitions, but identifies a third definition. The difference of net output ($v + s$, *variable capital + surplus-value*) consists of total net farm income excluding government payments and gross rental value of farm dwellings, taxes on farm property, net rent to nonfarm landlords, and hired labor.[2] Since hired labor expenses is part of variable capital, the concept of surplus-value used in the data consists of profits, property taxes, and rent. I shall leave it to Lianos

[2] This is apparent from the contents of output and constant capital described in the footnotes to Table 1 and the contents of total net income from the Farm Income Situation [5].

Table 3. Organic composition of capital: Lianos-Paris estimates and corrected estimates; rate of exploitation estimates: Lianos-Paris, three alternative estimates, 1949–1972

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Year | Lianos-Paris organic composition of capital | Organic composition of capital | Lianos-Paris rate of exploitation | Corrected Lianos-Paris rate of exploitation | Alternative rate of exploitation | Alternative rate of exploitation |
| 1949 | .95 | 1.457 | .01 | .232 | .389 | .764 |
| 1950 | 1.09 | 1.701 | .08 | .299 | .541 | .988 |
| 1951 | 1.17 | 1.786 | —.07 | .149 | .395 | 1.037 |
| 1952 | 1.23 | 1.807 | .03 | .258 | .445 | .916 |
| 1953 | 1.24 | 1.733 | .14 | .389 | .453 | .718 |
| 1954 | 1.33 | 1.902 | .21 | .497 | .570 | .748 |
| 1955 | 1.42 | 1.975 | .29 | .580 | .656 | .656 |
| 1956 | 1.54 | 2.057 | .38 | .661 | .661 | .661 |
| 1957 | 1.69 | 2.272 | .42 | .721 | .721 | .681 |
| 1958 | 1.91 | 2.496 | .47 | .815 | .815 | .988 |
| 1959 | 1.98 | 2.532 | .56 | .845 | .845 | .715 |
| 1960 | 2.09 | 2.611 | .68 | .984 | .942 | .852 |
| 1961 | 2.21 | 2.735 | .79 | 1.123 | 1.028 | .934 |
| 1962 | 2.42 | 2.974 | .84 | 1.169 | 1.070 | .972 |
| 1963 | 2.56 | 3.114 | .98 | 1.364 | 1.212 | 1.008 |
| 1964 | 2.68 | 3.174 | .97 | 1.331 | 1.123 | .866 |
| 1965 | 2.90 | 3.356 | 1.11 | 1.591 | 1.320 | 1.212 |
| 1966 | 3.21 | 3.547 | 1.05 | 1.451 | 1.137 | 1.242 |
| 1967 | 3.37 | 3.478 | 1.13 | 1.558 | 1.141 | .938 |
| 1968 | 3.48 | 3.462 | 1.08 | 1.488 | .992 | .845 |
| 1969 | | 3.530 | | 1.597 | 1.066 | .969 |
| 1970 | | 3.577 | | 1.825 | 1.155 | .965 |
| 1971 | | 3.838 | | 2.077 | 1.342 | .992 |
| 1972 | | 4.142 | | 2.003 | 1.278 | 1.227 |

Sources: Col. 1 is from [2, p. 574, Table 2, col. 4]. Col. 2 is col. 7, Table 1 ÷ (col. 4, Table 1 × col. 5, Table 1). Col. 3, from [2, p. 574, Table 2, col. 7]. Col. 4 is col. 6, Table 2 ÷ col. 5 Table 2. Col. 5 is the rate of exploitation calculated using the index of prices paid by farmers for production items (1957–59 = 100) to deflate constant capital and composite wage rate. Col. 6 is the rate of exploitation calculated using current dollar data.

and Paris to identify the correct definition or at least the one they meant to use. For ease of comparison, the third definition is also the definition used in my calculations.

The only explicitly stated objective appears in their last paragraph, "to provide a test of the prediction of increasing misery for one sector of the economy." Previously they had stated "the empirical results show unambiguously that in a relative sense the share of labor is declining and misery of farm laborers is increasing" (p. 576). Thus they feel they have provided a test and the results of the test were positive. The empirical facts suggest their conclusion is not universally true. The last column of Table 3 presents Lianos and Paris' computations in current dollars. We find we have lost their smooth increasing trend in the rate of exploitation. We find their conclusion of a positive test of the prediction of increasing misery for the agricultural sector rests on the fact that the index of prices paid by farmers has risen faster than the index of prices received. Lianos and Paris have rediscovered the cost-price squeeze and renamed it! The point, however, is not that the authors have merely come up with a new name for a familiar phenomenon, but rather that while their stated objective was methodology oriented (providing a test of the prediction of increasing misery), they failed to explain the special set of circumstances (data series deflated by selected price indices) under which these results were obtained and to explain why this set of transformed data is more meaningful for analysis than the raw data. If this was the objective of the paper, Lianos and Paris failed to develop it.

It is unfortunate that while writing an otherwise good article, Lianos and Paris chose to ignore fundamental concepts of good research procedure. The haunting thought is that their neglect of good research procedure is not unique. Lianos used the same faulty data set (improperly deflated wage rate) as a basis for a previous article [1]. This article has gone unchallenged for over two years.

Can our profession be excused in this instance because the data manipulation was complicated and thus difficult to check?

One can only speculate how many of our journal articles and unusual results like Lianos-Paris' negative rate of exploitation are based on improperly prepared or incorrectly used data. It would be sad if this comment discourages journal articles based on simple data manipulations and encourages authors to submit articles where their data manipulations are such that no one is likely to check them. Rather, I hope it encourages authors to pause briefly before submitting articles to check the data and computations and make sure that the relationship between the data, the analysis, and the rest of the paper is the intended one.

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# AMERICAN AGRICULTURE AND THE PROPHECY OF INCREASING MISERY: COMMENT*

'. . . the cold metal of economic theory is in Marx's pages immersed in such a wealth of steaming phrases as to acquire a temperature not naturally its own. Whoever shrugs his shoulders at Marx's claim to be considered an analyst in the scientific sense thinks of course of those phrases and not of the thought, of the impassioned language and of the glowing indictment of 'exploitation' and 'immiserization'. . . .

Joseph Schumpeter, *Ten Great Economists* [5, p. 25]

In a recent article in this *Journal* [3], Theodore P. Lianos and Quirino Paris utilized Marx's Doctrine (Prophecy) of Increasing Misery to explore the phenomena of a decline in the relative share of labor in American agriculture. According to them, this share decreased from 72 percent in 1949 to 33 percent in 1968 [3, p. 570]. Their reasons for utilizing this alternative framework after investigating the sources of change within the framework of neoclassical production theory are that a balance in intellectual diet is healthy; that given the recent development of radical economics, this approach may be viewed as an attempt to introduce scientific radicalism into the field of agricultural economics; and to determine if American agriculture may be taken as a realization of Marx's prophecy of increasing misery. It is my *belief* that while these are commendable objectives, this article may, nevertheless, obfuscate rather than clarify an explanation of the transitional phase through which American agriculture is passing.

As a point of departure, however, I feel the authors should be commended on improving the balance in intellectual diet. As an agricultural economist interested in the history of economic thought, I for one welcome empirical studies that apply past theories to present data. What I find objectionable, however, is utilizing past theories for more than intellectual exercises, if the language in which they are couched muddies up already cloudy issues. This is especially true in this case since the term "misery," as much of Marx's vocabulary, is based on emotionalism rather than accepted (even at that time!) economic terminology.

Now, the difficulty with promulgating theories couched in emotion-laden, value-ridden terms is that non-scientists, or scientists who want to prove a point, use them without the necessary qualifications. In the case of the term "misery," contemporary usage defines it as implying a condition of great wretchedness or suffering because of pain, poverty, etc. It does not, and is not, intended to convey a meaning of adjustment to changing conditions. If possible, it is even worse than the locutions "farmers share," "the family farm," the "cost price squeeze," or a host of other expressions recently identified and condemned [2]. Since the purpose of language is to assist in communication, the term "misery" certainly should never be used today in the sense the authors have—"not a declining wage rate or a declining share of labor, but a declining share of labor as a proportion of total net income. . ." [3, p. 573] *even though this is the manner in which Marx uses it.* Thus the authors are wide open to criticism since their intent is to drag this doctrine out of the attic of classical economics and add it to the economists' tool kit for use in normative problems. My opinion is that instead of advancing "scientific" radicalism, which was another one of their objectives, this theory detracts from it.

A second comment refers to interpretations of Marx. The authors have determined that the misery factor should be based on relative shares, but as Robert Freedman has noted, "what Marx meant when referring to the 'increasing misery' of the worker has been the subject of considerable comment' [1, p. 68]. This authority points out that Marx himself did not specify whether the absolute value of goods and services available to the workers would decline or if the laborers' share of a rising national income would be smaller [1, p. 68]. In a similar vein, it is questionable whether this theory can be applied to one sector and labor's share of its income (as the authors have done) or if it only refers to labor's share of *national* income as Robert Freedman interprets it. Unfortunately, the authors have neglected to point out the seriousness of these interpretive issues or even that they are open to speculation.

A third criticism refers to the author's journey into normative (policy) economics. They state, "the empirical results show unambiguously that in a relative sense the share of labor is declining and misery of farm laborers is increasing" [3, p. 576]. They note that although absolute levels of farm laborer incomes have increased, this measure of well being must be rejected in favor of the relative share because "once income is above the subsistence level an individual's dissatisfaction is determined by the difference between his income and his aspirations as formed by the economic well-being of others" [3, p. 576]. The difficulty is they have not offered one shred of evidence to support a hypothesis concerning individual dissatisfaction—in fact, they have not even observed that their assertion is nothing but a hypothesis.

One isolated case would not be worth mentioning.

* The author is indebted to Vito Blomo, Conrad Fritsch, and Lonnie Jones for critical reviews and suggestions on earlier drafts of this paper.

This lack of regard for the reader's sensibilities is, however, further promulgated by the authors' conclusion that "for the great majority of workers whose agricultural jobs are eliminated by such a technical progress it is extremely difficult, if not impossible, to find alternative jobs in other sectors of the economy due to the sharp asymmetry of the corresponding labor markets" [3, p. 574]. This then supposedly results in what they designate, following Marx's lead, as a large Industrial Reserve Army. They do note that this is primarily a phenomenon of recessions, but they do not observe that the U. S. economy has faced few recessions since the authors' period of analysis began and that these recessions have simply caused *temporary* adjustment probelms anyway. I would argue (without proof) there is no "great" unemployed Industrial Reserve Army of farm laborers today in either the rural or urban areas of the United States. In any event, a reference by the authors to time series data on agricultural laborers forced out of a job and subsequently unemployed both in the short and long run would have assisted the reader.

I have one final comment. The authors state that if the existing trend (toward larger farms) continues, both capital and land owners will be completely separated from farm laborers, economically speaking. They identify this as one of the "important" questions concerning the future of the agricultural sector. Implicitly, normative judgments follow. Any one directly or indirectly concerned with policy would naturally wonder if something should be done to prevent this further dichotomization. To me, a logical question is this: should technological change be constrained to slow this outmigration?

Whenever the subject of technological unemployment surfaces (and basically this is the issue), I cannot help but be reminded of the debates in the English Parliament at the time the brilliant economic theoretician David Ricardo was a member. It must be recalled that at that time misery, and by this I mean misery as commonly defined today, was rampant among the farm labor class and those migrating to the city. At one point Ricardo was found giving a speech about a plan by the Utopian Socialist Robert Owen. The *Hansard* newspaper paraphrases Ricardo as saying:

> Mr. Owen's plan proceeded upon this—he who was such an enemy to machinery, only proposed machinery of a different kind: he would bring into operation a most active portion of machinery, namely human arms. He would dispense with ploughs and horses in the increase of the productions of the country, although the expense as to them must be much less when compared with the support of men. [6]

Then, as now, the issues of adjustment have been of critical importance. What is not so apparent is that there are benefits as well as costs. Unfortunately Marx's theory only concentrates on the latter, thus limiting its usefulness. In any event, researchers interested in analyses of this type might well begin their literature review with Padfield and Martin's *Farmers, Workers, and Machines* [4]. It is, in fact, a good place for nostalgic farm fundamentalists to begin a survey of what constitutes misery among farm laborers.

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# AMERICAN AGRICULTURE AND THE PROPHECY OF INCREASING MISERY: COMMENT

I read the Lianos and Paris article [2] with great interest because I was interested in improving my intellectual diet and in learning more about scientific radicalism. On the other hand I had little hope of discovering the trend in misery as measured by the Marxian concept of labor's share of output because the level of misery cannot be measured in this way when factor proportions are changed and personal income distribution differs from functional distribution. I was disappointed in the extent to which my intellectual diet was improved and in the lack of advancement in scientific radicalism.

In Marxian analysis there was no distinction between labor income and the worker's share of income. It was essentially assumed that workers owned no capital and owners of capital supplied no labor. Moreover, there were no income transfers through the public sector. The functional distribution of income in Ricardo's analysis was a means of discovering the laws that governed the distribution of given levels of income and in neoclassical economics income distribution was developed as a tool for analyzing questions of resource allocation and factor values. Levels of personal wealth and income from all sources, life expectancy, and health conditions are much more accurate indicators of misery and welfare than is a factor's share of value added. If the number of workers were reduced to 2 and they received 1 percent of the national income, they could enjoy a lot of misery! The way to maximize labor's share of income is to eliminate capital and land. Would this decrease the misery of labor? What has happened to labor's share of income over time in noncapitalistic countries? I would hypothesize that it has decreased.

It is erroneous to deal with the U. S. agricultural sector in isolation from the rest of the economy, despite imperfections in the factor markets. In 1971, 53 percent of farmers' income was received from off-farm sources; of those units with farm sales of less than $2,500, 89 percent of the income came from off-farm sources [6, p. 4]. Farm workers also receive income from nonfarm jobs. This income was omitted, yet it as well as farm wages must be related to misery and welfare. In the period 1950 to 1971, outmigration of farm population, as an annual average, amounted to 1.1 million persons in 1950–55 and 550 thousand in 1965–71 [6, p. 51]. Unemployment rates in agriculture have exceeded those in the nonagricultural industries, but the two rates have been closely correlated, and both have declined since peaks were reached in 1958 [6, p. 55]. Thus it cannot be said that the farm sector is isolated from the nonfarm sectors, nor is it true that all displaced persons join the ranks of the unemployed. As for the movement toward a dichotomy of employers and hired workers, the share of hired workers in total farm employment increased from 23.5 percent in 1950 to 27.3 percent in 1961. It has since fluctuated between the 27.3 percent reached in 1961 and 25.5 percent in 1968 [6, p. 17] Thus, since 1950 approximately 25 percent of farm workers has been classed as hired labor.

In the value added calculation [2, p. 571], what is included in the deduction for "expenses for hired labor"? I do not believe that wages and farm produced perquisites should be deducted. In the case where the farmer uses his own land and capital to exploit his own labor, and that of his family, would he be better off if he used no capital?

I agree that "Marx has been (and is) discussed widely, read rarely, and misunderstood often" [2, p. 573]. One of the reasons for the rare reading probably is the cumbersome nature of the presentation, the mixture of emotion and logic and the extensive reading required to glean the essential elements. But I believe the concept of labor's share of income as a measure of laborers' misery is not likely to add to the understanding of relevant elements of Marxian analysis nor is it likely to excite members of our profession sufficiently to induce large numbers to read the original material. Some of the more relevant matters include economic and social conflicts and collective action in addition to those that may arise between employer and employee and the dynamics of technological change under conditions of monopolistic competition. The more general statement of "exploitation" is given in the form: "M–C–M', where $M' = \Delta M =$ the original sum advanced, plus an increment. This increment or excess over the original value I call 'Surplus-value'" [3, p. 168]. Thus the capitalist starts with money (M) and employs labor or any other factor (C) and produces M' which is equal to cost plus a profit (surplus). Thus M' must exceed M or the system breaks down. But in this case any factor, including capital, can be exploited.

Actually, Marx's skimpy treatment of farming was extended in a more sensible way by Lenin [1] whose works were discussed by Rochester [5]. It was argued that small farmers with low incomes and tenants with insecure tenure would have a very short planning horizon and thus would mine (exploit) the soil and subject it to deterioration over time. Development of machinery would lead to economies of scale and in turn to substitution for labor and to continuously increasing sizes of units and reductions in numbers. This elimination of the smaller units would be accelerated by the periods of rising prices, when land would be mortgaged, followed by falling prices and incomes, when mortgages would be foreclosed. Were these problems recognized when our

government went into action with the Soil Conservation Service, credit, tenure, and price stabilization programs?

Another matter that is of more interest and less confused than labor's share of income concerns the policy recommendations given in the manifesto [4, pp. 30–31]:

> . . . the following will be found pretty generally applicable:
>
> 1. Abolition of property in land and application of all rents of land to public purposes.
> 2. A heavy progressive or graduated income tax.
> 3. Abolition of all right of inheritance.
> 4. Confiscation of property of emigrants and rebels.
> 5. Centralization of credit in the hands of the State by means of a national bank with State capital and an exclusive monopoly.
> 6. Centralization of the means of communication and transport in the hands of the State.
> 7. Extension of factories and instruments of production owned by the State, the bringing into cultivation of waste lands, and the improvement of the soil generally in accordance with a common plan.
> 8. Equal obligation of all to labor. Establishment of industrial armies, especially for agriculture.
> 9. Combination of agriculture with manufacturing industries, gradual abolition of the distinction between town and country, by a more equable distribution of population over the country.
> 10. Free education for all children in public schools. Abolition of children's factory labour in its present form. Combination of education with industrial production, etc.

I shall comment on each of these proposals in the order in which they were listed.

1. We have not abolished property in land, but in early policies (Homestead Act, for example) a broad property base was encouraged. There are taxes on land ownership and income from land as well as restrictions on use and programs to prevent soil deterioration.
2. We have a progressive income tax at the federal level and in a number of states.
3. Rights to inheritance have not been abolished but are constrained by taxation.
4. This item is one of the frequent injections of inconsistency and emotionalism.
5. We have a central banking system with other monetary and fiscal controls.
6. Communication and transportation systems are not State owned, but they are regulated in rather comprehensive fashion.
7. Industry is not State owned, but it is subject to controls through taxation, antitrust laws, quality standards, and laws affecting wages, hours, and working conditions.
8. We have assumed that all persons able to work were expected, but not compelled, to do so. They could live on other sources of income, when available, they could draw unemployment compensation when unemployed, or they could starve!
9. The meaning of this item is not entirely clear, but the distinction between urban and rural areas has been diminished.
10. Education is not free but it does receive substantial public support, children are required by law to attend school and constraints on child labor are covered in our labor legislation.

It would be interesting to determine the extent to which the U. S. economy might have followed the more relevant pattern of behavior (I consider labor's share of income to be irrelevant) of unrestrained competition leading to monopoly and extreme class dichotomies of property owners and nonproperty owners and masses of workers at subsistence levels of living and economic and political power more centralized, if public action along the lines suggested in the manifesto had not been taken.

Finally, I believe the need for continuous public action to cushion the shocks that occur in a dynamic society can be inferred from Watkins' very succinct statement [7, pp. 180–181]:

> From the standpoint of other members of the community, the great defect of the middle-class revolution was its tendency to upset the habitual bases of social life. Habit rather than choice is the normal basis of human action. . . . To the extent that it involves the abandonment of settled habits, therefore, innovation is painful. This particular element of cost was neglected in the hedonistic calculus of the Enlightenment. . . . Preoccupied with the advantages of technological progress, enlightened economists were willing to allow the discoverer of new methods of production to deprive less efficient producers of their traditional livelihood, immediately and without compensation, through the operation of free competitive markets. For intelligent and adaptable members of the middle class, the costs of change were not excessive in comparison with the profits. For those who had to bear the brunt of innovation, the situation was disastrous. Absolute adaptability to the requirements of a constantly changing society is an impossible standard of behavior for ordinary men.

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# AMERICAN AGRICULTURE AND THE PROPHECY OF INCREASING MISERY: COMMENT

Lianos and Paris have failed to make their case that the trends in the share of wages in agriculture verify Marx's prophecy of increasing immiseration [2]. To begin with, Marx saw agriculture as a very unique sector of the economy.

One special aspect of agriculture was its very low organic composition of capital, written as $c/v$. Marx took this idea from Adam Smith, who wrote [9, p. 344, and cited in 3, Vol. II, pp. 360–361]:

> No equal capital puts into motion a greater quantity of productive labour than that of the farmer . . . In agriculture too nature labours along with man; and though her labour costs no expense, its produce has its value, as well as those of the most expensive workmen.

Thus, for Marx [4, pp. 109–110],

> On the whole it can be assumed that under the cruder, pre-capitalist mode of production, agriculture is *more productive* than industry, because nature assists here as a machine and an organism, whereas in industry the powers of nature are still almost entirely replaced by human action. In the period of the stormy growth of capitalist production, productivity in industry develops more rapidly as compared with agriculture, although its development presupposes that a significant change as between constant and variable capital *has* already taken place in agriculture, that is, a large number of people have been driven off the land. Later productivity advances in both but at an uneven pace. But when industry reaches a certain level the disproportion must diminish, in other words, productivity in agriculture must increase relatively more rapidly than in industry. This requires: 1. The replacement of the easy going farmer by the businessman, the farming capitalist; transformation of the husbandman into a pure wage labourer; large-scale agriculture, i.e., with concentrated capitals. 2. In particular, however: mechanics, the really scientific basis of large scale industry.

As agriculture mechanizes, the ratio of $v/s$ should fall since increased capital makes workers more productive [3, Vol. 1, p. 523]. Since $S'_L$ can be rewritten as $1/(1 + v/s)$, the "share of labor" in agriculture should originally be higher than in industry. With the advent of agricultural mechanization, it should fall far more rapidly than in industry until the shares in agriculture and industry are equalized assuming that the two sectors have an equal organic composition of capital. The importance of this assumption will be discussed in a moment.

Thus the fall in the share of labor in agriculture cannot simply be taken as "a realization of Marx's prophecy of increased misery" [2, p. 570]. In fact, Marx might be more in sympathy with the earlier paper by Lianos [1] concerning basic technological change since he wrote [3, Vol. III, p. 690] the following:

> Although profit arises only from surplus-labour, consequently only from the employment of variable capital, it may still seem to the individual capitalist that living labour is the most expensive element in his price of production which should be reduced to a minimum before all else.

However, since the historical role of agriculture is to provide a reservoir of cheap labor, a reserve army of the marginally employed, the statistics of Lianos and Paris do represent a part of the mechanism which contributes to the continued (relative?) immiseration of labor since the exodus of labor from the farm has helped to hold down wages in the city.

Marx's analysis of agriculture was very subtle, and while it is true that increasing immiseration would imply a decreasing $S'_L$, his prophecy was far more specific. He foresaw the rapid mechanization of agriculture where most economists of his day tended to forecast stagnation [7].

The falling value of $S'_L$ in agriculture does not seem to be matched by a comparable fall in industry. For instance, the ratio of wages to value added in industry fell from 40.7 percent in 1947 to 30.7 percent in 1969, while Lianos and Paris' estimate of the share in agriculture fell from 72.2 percent in 1949 to 33.3 percent in 1968 [8, p. 27]. The apparent convergence of these two ratios suggests the catching-up process predicted by Marx; however, the process is still more complicated.

The organic composition of capital in agriculture is still relatively low. A crude estimate of the 1968 value of capital per worker is $20,000 [5, p. 231]. In agriculture, the value of capital per worker for that year was approximately $11,000 [10, p. 27]. However, when land is included as a capital asset, the organic composition of capital in agriculture turns out to be about two times as high as the national average judging by the value of capital per worker [5, p. 231].

The low organic composition of capital in agriculture implies that farmers have not yet caught up with the rest of the economy in mechanizing. Yet judging by the ratio of wages to value added, the value of $s/v$ in agriculture is not much different from the ratio of $s/v$ in industry.

These statistics can be more easily interpreted by looking at the rate of profit, $s/(c + v)$, which can be rewritten as $(s/v)/(c/v) + 1$. If $s/v$ is equal in two sectors, and $c/v$ differs from one sector to another, then the rates of profit cannot be

equal. That is, the rate of profit would be higher in agriculture than in industry.

However, if the value of land is included in the measurement of $c$, then the rate of profit is lower in agriculture. Marx would tend to accept the value of $c$ inclusive of land values when discussing the behavior of the individual farmer while excluding the value of land when discussing agriculture.

Marx, writing in England where most farmers rented their land, saw farmers who had to accept the rent of land as a part of their production costs. Thus, assuming a high value $c/v$ and the national average of $s/v$, farmers would earn a less than average rate of return. This situation corresponds with the reality of U. S. agriculture where the rate of return to agriculture is relatively low [6]. On the other hand, from the point of view of the agricultural sector as a whole, the low value of $c/v$ is appropriate. Marx writes [3, Vol. II, pp. 332–3]:

> Why must the *price* be so high that it equals the cost-price, i.e., the capital advanced plus average profit? Because of the competition of capitals in different branches of production and the transfer of capital from one branch to another. That is, as a result of the action of capital upon capital. But by what action could capital compel landed property to fall to the cost-price? Withdrawal of capital from agriculture cannot have this effect, unless it is accompanied by a fall in the demand for agricultural produce. It would achieve the reverse, and cause the price of agricultural produce to rise above its value. Transfer of capital cannot have this effect either. For it is precisely the competition of capitals amongst themselves, which enables the individual capitalist that he should be satisfied with 'an average profit' and pay over to him the overplus of the value over the price affording this profit . . .
> Even in England a large part of the fertile land is artificially withdrawn from agriculture and from the market in general, in order to raise the value of the other part.

Here again, in his theory of rent, Marx follows Smith, who wrote:[1]

> There are some (mines) of which the produce is barely sufficient to pay the labour, and replace, together with its ordinary profits, the stock employed in working them. They afford some profit, but no rent to the landlord. They can be wrought advantageously by nobody but the landlord, who being himself undertaker of the work, gets the ordinary profit of the capital which he employs in it. . . . The landlord will allow nobody else to work them without paying some rent, and nobody else can afford to pay any.

[1] Marx seems to follow Smith most often when discussing agriculture and Ricardo on the subject of industrial production.

Thus, in U. S. agriculture, although the return to capital is small, the return to land in the form of appreciation of land values makes agriculture a relatively good investment [6]. Once more Marx's analysis seems appropriate.

To analyze the real meaning of movements in relative shares require some consideration of the forces which determine the role of land in agriculture since Marx's meaning of immiseration concerned the worsening of the position of labor due to the increasing importance of constant capital and not to the increasing importance of land. For instance, Marx recognizes that the monopoly power of landlords will be less in colonies where the state dispenses cheap land [3, Vol. I, p. 768].

A final problem with Lianos and Paris' statistics concerns the role of non-farm inputs. In a peasant agriculture, many farm produced goods are not costed out when the farmer calculates his rate of return; that is, manure, seed, and other inputs which the farmer produces on the farm are not considered to be costs of production. As capitalism matures, these inputs are sold commercially, and the farmer either purchases them from non-farm businesses or he considers them an actual cost. This change affects the accounting of the statistics in question since the increased importance of non-farm inputs will naturally reduce the value of $S'_L$ for farm workers. Here again, Marx studied this problem and understood what was happening before other economists of his day [see 3, Vol. 1, p. 305].

Marx did not intend his system to be applied in a mechanistic way. For him, the study of economics required a thorough analysis of the institutional framework of the economy. A study of relative shares, more completely in the Marxian tradition, would require some discussion of farmers' dependence on outside credit until harvest time and some consideration of the struggle between urban and rural powers, which he considered central to the development of agriculture [see 3, Vol. 2, p. 242 and Vol. 1, p. 352].

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# AMERICAN AGRICULTURE AND THE PROPHECY OF INCREASING MISERY: REPLY

Borrowing the terminology from the political arena, the four authors above have criticized our paper [1] both from the right (three) and from the left (one). The criticisms coming from the right (Simpson [7], McPherson [2], and Schluter [5]) essentially constitute an objection to adopting a Marxian framework for analyzing the behavior of the relative income share of labor. This objection is deeply rooted in economists reared only at the neoclassical smorgasbord where much of the food is flavorless. Thus, Simpson does not like to talk about "misery," but rather of "problems of temporary adjustment." McPherson rejects the idea that labor can be "exploited" and prefers to dilute it into the symmetric but lifeless assertion that "any input, including capital, can be exploited." Schluter—although not explicitly discussing the paper's framework—attempts to discredit it by contributing erroneous interpretations of the data series and of the Marxian hypothesis, which would nullify the trend of increasing misery. From the left, Perelman [3] suggests that we have not done enough and—(horror!) using neoclassical concepts—indicts us for misinterpreting Marx's thought.

Let us analyze the various authors' comments in greater detail. Schluter seems to say (with an abundance of unnecessary handwaving and an authoritative air) that even if the conceptual framework of our paper is accepted, our data contain computational errors that render the results questionable. He is dead set in proving us wrong on all four arithmetic operations. As it turns out, we must apologize to the readers and to Mr. Schluter for a number of imprecisions appearing in our paper. But having done this, it will be shown—with the skillful clerical help of Mr. Schluter—that the original results remain valid.

The first imprecision is that the wage rate used in the computation of the wage bill is not the "composite farm wage rate" (as we assert in the text of the paper), but rather the "hourly wage rate without board or room." It is deflated to 1957–59 dollars and, thus, consistent base periods were used throughout. No computational errors were made, not even in the 1949 estimate of the rate of exploitation, as Schluter claims. Schluter's exercise using the composite wage rate is an alternative choice of "correct data" which strengthens the case we tried to establish.[1] For this we are grateful to him. As it can be seen from his Table 3, column 4, the rate of exploitation has increased over eight times between 1949 and 1972.

Obviously dissatisfied with this result, Schluter criticizes us for the selection of the deflators and experiments with recalculation of the rate of exploitation employing—without a convincing argument—a different index of price paid by farmers. The result is that the rate of exploitation has increased only (!) by 3.3 times between 1949 and 1972. Still unhappy, Schluter calculates a new rate of exploitation, at current prices this time. This is incorrect, since Marx's analysis of the division of the pie and the derived prophecy is done in real and not nominal terms. This is the misinterpretation of the Marxian framework which alone allows Schluter to achieve his goal: the rejection of the increasing misery hypothesis. Schluter's lecture on the existing data series is as useless as gratuitous. Obviously, we were interested in utilizing a definition of value added (and not gross farm product) together with the associated components of capital and labor (which do not exist in the "survey of current business"). Furthermore, the risk of committing a small error of double counting by considering the livestock purchase as a capital item was undertaken to avoid the bigger error of underestimating the series of capital.

The other verbal imprecision in our paper deals with the definition of surplus value. In Marxian term the surplus value is that portion of value produced by workers but appropriated by capitalists. Furthermore, the activity of workers is the only generator of additional value. The surplus value so defined is the source of income for the capitalists which, in modern terms, can be assimilated to pure profits, rent and interests. In the original three-department scheme of Marx, taxes are not explicitly accounted for. When this is done, they are considered as that part of the surplus value used to maintain the bureaucracy, police, armed forces of the capitalist state: the membership fee to the capitalist club. Hence, taxes should be considered as part of surplus value. The fact that property taxes were not explicitly mentioned in the text of our paper has misled Schluter. On the other hand, there is no justification to subtract only property taxes and not, say, income taxes.

Simpson attributes to us the intent "to drag (the Marxian) doctrine out of the attic of classical

[1] While preparing the background material for the paper, more than three years ago, we experimented with the composite farm wage rate. In the attempt to make the argument more convincing, it was decided to employ the data series least favorable to the hypothesis for the final version of the paper. We, of course, apologize to the reader for not adjusting the text corresponding to the description of the wage data. The USDA-SRS practice of periodically revising the data series even as far back as 10 years or more is responsible for minor discrepancies that can be detected between the data used in the paper and the last adjusted series of available information.

economics." He objects to this because it implies "promulgating theories couched in emotion-laden, value-ridden terms." Unlike Professor Simpson and, in general, the neoclassical economists, we do not find any contradiction between emotion and logic, so that these two moments of the spirit can harmoniously coexist without detracting from the explanatory power of Marxian theory. Thus, no apologies are offered for the use of the terms "misery" and "exploitation." Perhaps it is appropriate here to complete Simpson's citation of Schumpeter's writing about Marx: "the foes, who resented (Marx's) attitudes and the setting of his theoretic argument, found it almost impossible to admit that in some parts of his work he did precisely the kind of thing which they valued so highly when presented by other hands" [6, p. 25].

Simpson's main objection (and common to Professor McPherson) deals with the use of relative income share as the indicator of workers' well being (or misery). This controversy is of old vintage and to Simpson's "authority" (R. Freedman) we can quote less ambiguous students of Marx (T. Sowell [8], for example), who support the point of view expressed in our paper. In more positive terms, if Simpson accepts Marx's definition of the rate of surplus value or rate of exploitation, there should not intervene any difficulty in accepting also the relative income share notion as a measure of workers misery, since the two are univocally related. In fact $S'_L = 1/(1 + R)$, where $S'_L$ is the relative share of labor and $R$ is the rate of surplus value. Our suspicion, however, is that Mr. Simpson wishes to reject Marx's framework altogether, which is the only way for him to disagree with our use and interpretation of the relative income share of labor and its trend.

A final point on Simpson's comments regards his dislike for our alleged "journey into normative (policy) economics." Although it is difficult for us to recognize any normative character in the quotations of our paper presented by him, we cannot pass under silence his peculiar view that the documented trends may be simply interpreted as "temporary adjustment problems." Workers' lives are a series of short-run (temporary) experiences. The concept of long-run is certainly useful for analytical purposes, but it would be deceiving to derive comfort about agricultural workers' conditions by minimizing the importance of "temporary" but painful "adjustments problems." To paraphrase Marx, it seems to us that the concept of "long-run" has become the opium of neoclassical economists.

McPherson's comments present various points in common with those of Simpson. He too discards *a priori* Marx's framework, and reiterates the superior performance of neoclassical analysis. Clearly, our paper was not intended to be an evaluation of the two doctrines, which would require a much wider perspective.

McPherson attempts to ridicule Marx's thought with a series of paradoxical, if not absurd statements, which would indicate his incomplete understanding of the Marxian economic system. He asserts that "the way to maximize labor's share of income is to eliminate capital and land," whereas he should have said that such an objective can be achieved by eliminating capitalists and landowners. Then, talking about exploitation, he reaches the conclusion that "any factor, including capital, can be exploited," a typical neoclassical position which does not recognize the facts of economic life. Such a position would hold that it is indifferent to talk about capital hiring labor or about labor hiring capital. In the Marxian model, constant capital cannot be exploited because the production process involves no quantitative alteration of its value. It is only labor which can be exploited because in the production process it undergoes an alteration of value.

McPherson's main point seems to be that it is more interesting to look at the policy implications of Marxian economics rather than devote time to the examination of relative share. He states that "the concept of labor's share of income as a measure of laborer's misery is not likely to add to the understanding of relevant elements of Marxian analysis." We have already discussed this same criticism in replying to Simpson's comments. However, since it is very likely that other readers will hold McPherson's opinion, it is important to document further the incorrectness of this point of view by enlarging the discussion to other "relevant elements of the Marxian" system of thought, not explicitly presented in our paper.

In several quarters and over many years, Marx has been branded as a poor logician because—it was claimed—his law of the falling rate of profit is inconsistent with the theory of increasing misery. Since in many points of his work Marx had clearly in mind the notion that misery was not related to a particular and unchanging level of subsistence, it is important to underline here that the use of relative labor share eliminates the alleged logical inconsistency between the two laws.[2] The algebra of this statement is sufficiently simple to be left to the interested reader. In words, a greater quantity of output over the years can be divided into constant capital, variable capital and surplus value, in such a way to obtain a reduction in the rate of profit (not of the total profits) and of the output's proportion distributed to workers. Hence, if Marx is interpreted in his own framework, it will not be difficult to understand why the relative income share of workers is an important component of his thought.

Perhaps the most revealing soul of McPherson's comments lies in the evaluation of the achievements

[2] When a linear model of joint production is considered, it can be shown that a falling rate of profit is consistent with a falling real wage even if labor is the only original factor of production.

of American society judged against the recommendations of the Communist Manifesto. It would appear that, according to his judgment, the United States has gone a long way to fulfill the conditions of a communist society.

We have two final points. Perelman affirms that the trend in the income share of labor reveals only the "catching-up" of agriculture with respect to other sectors of the economy rather than the increasing misery of workers. We are puzzled by this neoclassical reasoning coming from a student of Marxian thought. Interpretation of the trend statistics as a catching-up problem is germane to Simpson's explanation in terms of "adjustment problems." It is difficult for us to understand why the "catching-up" process is not associated with exploitation and increasing misery.

Perelman's discussion of the organic composition of capital is also incorrect because it is carried out using neoclassical concepts. In fact, he confuses the organic composition of capital of Marx with the capital-labor ratio of "vulgar" economists, and he insists that "the organic composition of capital in agriculture is still very low." In support of his assertation, he quotes *values of capital per worker* and, with a surprising twist, concludes that "the organic composition of capital in agriculture in terms of dollars, should be about 1/15 as large as the national average."

A correct comparison between $c/v$ ratios in the agricultural and the nonfarm sector can be made using the data series published in a paper by Sato [4]. It turns out that for the nonfarm sector the organic composition of capital is about 2.7, not too different from the corresponding estimate for agriculture. This suggests that the "catching-up" process is not lagging behind as much as Perelman asserts. Considering that the analysis was conducted with reference to a type of agriculture as advanced as the American farm sector, this conclusion is not surprising. It disposes also of Perelman's final criticism about the valuation problem of farm produced goods in a "peasant agriculture." Given the *non-peasant* character of American agriculture during the period considered, this problem is reduced to minimal proportions. Several other comments by Perelman are complementary to our presentation and raise no objection.

His comments also contain two interesting research questions, namely, the relationship between employment, wages, and land values, and the role of institutions in the process of labor exploitation in a capitalist economy. The first question we discussed briefly in an attempt to show how farmers can exploit their own labor as well as their families. Both questions are worth investigating, and we hope Perelman will undertake this task.

In conclusion, if Marx is interpreted and understood on his own terms, the results of our paper maintain their validity. Although exploitation and increasing misery generally constitute only a concept alien to the neoclassical economist, they seem to be an inescapable reality for agricultural workers.

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# SOCIAL RATES OF RETURN AND OTHER ASPECTS OF AGRICULTURAL RESEARCH: THE CASE OF COTTON RESEARCH IN SÃO PAULO, BRAZIL: COMMENT

The recent paper by Ayer and Schuh [1] estimated internal rates of return to cotton research in the state of São Paulo, Brazil and found that the rate of return probably lies in the interval between 77 and 110 percent per year. These estimated rates of return, apparently surprising even the authors, substantially exceed estimates for other successful research programs and force the authors to ask, "Why was the rate of return so high?" The authors argue that their results derive basically from the 75 percent increase in fiber productivity obtained by the research station in São Paulo over traditional varieties. This comment will show that the Ayer-Schuh results are overestimated because the study uses only experimental station results rather than farm-level yields, and the partial equilibrium framework of the study ignores important costs.

## Experimental versus Farm-level Yields

The benefit streams in the Ayer-Schuh paper arise from supply shifts induced by the planting of improved cotton varieties. To measure the extent of the induced supply shifts, Ayer and Schuh develop a shift factor $K$ "where $K$ is determined by the difference in fiber yield between the old and improved varieties and the proportion of each new variety planted" [1, p. 559]. The shift factor, $K$, in the Ayer-Schuh study is determined solely from experimental station field trials which, as is well known, overestimate farm-level yields. Historical farm-level yield data for cotton exist for the state of São Paulo [5, 6, 7], and these data are presented in Table 1. A new estimate of the shift factor, $K'$, based upon these farm-level yields is included in the table. $K'$ has been computed by dividing yearly farm-level yields by the average yield obtained in the four-year period beginning 1924/25. Since improved seed varieties were first released in 1930, this average represents a reasonable estimate of the yield capabilities of the traditional varieties. As can be seen from the yearly data in Table 1 and the averages of $K$ and $K'$ presented in Table 2, $K'$ is substantially below $K$ until the mid-1960's and is in fact negative in 14 years. In other words, the traditional varieties apparently would have outyielded the improved varieties, *ceteris paribus,* in 14 of the years. As a result, the average value for $K'$ in the two periods 1936/1945 and 1946/1955 are $-3$ and $-14$ percent respectively, in contrast to the 37 and 44 percent estimates obtained from experimental results. Given this vast discrepancy, the rate of return generated from experimental data will greatly overstate the true rate of return. As will be shown below, even farm-level yield data will tend to overestimate the true return, due to the partial equilibrium framework employed by Ayer and Schuh.

## Rate of Return Using Farm-level Yield Data

Only upper boundary estimates of the internal rate of return to cotton research will be made here. In this limiting situation, the price elasticity of demand is assumed to be infinite, and elasticity of supply is assumed to be zero. Thus increased production from Brazil deriving from technological advances does not depress cotton prices, and the quantity of cotton supplied is not affected by price. As a result of these assumptions, social benefits are strictly dependent upon $K'$ and the prevailing market price, i.e., area *EAGD* in Figure 1. As shown in Ayer and Schuh's Table 3, this extreme case gives substantially higher internal rates of return.

Two estimates of social benefits have been made for São Paulo using the above assumptions and farm-level yields. In Case 1, denoted the "optimistic" estimate, all negative $K'$'s were treated as zeros, thus resulting in zero social benefits for the year in question. In other words, Case 1 assumes that the research station cannot impose losses on the society as a result of its research program; the traditional variety would have yielded similarly in that same year.[1] In Case 2, or the "pessimistic" estimate, it is assumed that it is possible for the research station to breed varieties which are less suitable or adaptable to local conditions than traditional varieties. Consequently, the research may impose costs rather than benefits upon society if it produces inferior varieties. Thus, during years when $K'$ is negative, the vertical supply curve *SCFS* ("improved" variety) lies to the left rather than to the right of *S'CFS* (traditional variety). Since it is recognized that farm-level yields reflect climatic conditions, insect infestations, etc., a three-year centered moving average of $K'$ was calculated in an attempt to reduce the impact of these stochastic influences. The resulting $\hat{K}'$ is an estimate of the varietal influence alone and results in negative $K''$s for the years 1935–1938 and 1944–1952. These subperiods are relatively long, and there is no evidence that atypical weather, insect, or disease conditions prevailed during these years.

Given the above assumptions, new estimates of the benefit streams were made, and the results are shown in Table 2; the cost estimates were not altered. The new benefit stream is not directly com-

[1] In actual fact, traditional varieties continued to be planted in the early 1930's, so that farm-level yields are a mixture of traditional and improved varieties.

Table 1. Farm-level seed cotton yields, fiber percentages, fiber yields, and supply shifts, São Paulo, 1924/25–1971/72

| Year | Farm-level Seed cotton Yield, Kg/ha. | Percent Fiber | Fiber Yield Kg/ha. | K′ Percent |
|---|---|---|---|---|
| 1924/25 | 940 | .30 | 282 | 0 |
| 1925/26 | 817 | .30 | 245 | 0 |
| 1926/27 | 830 | .30 | 249 | 0 |
| 1927/28 | 787 | .30 | 236 | 0 |
| 1928/29 | 640 | .30 | 192 | 0 |
| 1929/30 | 820 | .30 | 246 | 0 |
| 1930/31 | 1225 | .30 | 368 | 45 |
| 1931/32 | 786 | .297 | 233 | —8 |
| 1932/33 | 969 | .30 | 291 | 15 |
| 1933/34 | 1026 | .3115 | 320 | 26 |
| 1934/35 | 569 | .3107 | 177 | —30 |
| 1935/36 | 615 | .3144 | 190 | —25 |
| 1936/37 | 619 | .3111 | 193 | —24 |
| 1937/38 | 726 | .3218 | 234 | —8 |
| 1938/39 | 892 | .3355 | 299 | 18 |
| 1939/40 | 789 | .3349 | 264 | 4 |
| 1940/41 | 1066 | .3300 | 352 | 39 |
| 1941/42 | 749 | .3374 | 253 | 0 |
| 1942/43 | 838 | .3411 | 286 | 13 |
| 1943/44 | 744 | .3482 | 259 | 2 |
| 1944/45 | 369 | .3612 | 133 | —48 |
| 1945/46 | 448 | .3551 | 159 | —37 |
| 1946/47 | 406 | .3558 | 144 | —33 |
| 1947/48 | 499 | .3558 | 178 | —30 |
| 1948/49 | 655 | .3502 | 229 | —10 |
| 1949/50 | 379 | .3595 | 136 | —46 |
| 1950/51 | 527 | .3631 | 191 | —25 |
| 1951/52 | 724 | .3529 | 255 | 1 |
| 1952/53 | 676 | .3527 | 238 | —6 |
| 1953/54 | 754 | .3513 | 265 | 5 |
| 1954/55 | 997 | .3491 | 348 | 38 |
| 1955/56 | 659 | .3437 | 226 | —11 |
| 1956/57 | 758 | .3513 | 266 | 5 |
| 1957/58 | 957 | .3433 | 329 | 30 |
| 1958/59 | 1038 | .3488 | 362 | 43 |
| 1959/60 | 1059 | .3512 | 371 | 47 |
| 1960/61 | 915 | .3471 | 318 | 26 |
| 1961/62 | 1052 | .3497 | 368 | 45 |
| 1962/63 | 987 | .3510 | 346 | 37 |
| 1963/64 | 1175 | .3501 | 411 | 62 |
| 1964/65 | 799 | .3507 | 280 | 11 |
| 1965/66 | 1467 | .3509 | 515 | 103 |
| 1966/67 | 1407 | .3545 | 499 | 97 |
| 1967/68 | 1616 | .3543 | 573 | 126 |
| 1968/69 | 1626 | .3550 | 577 | 128 |
| 1969/70 | 1079 | .3553 | 383 | 51 |
| 1970/71 | 1104 | .3558 | 392 | 55 |
| 1971/72 | 1209 | .3552 | 429 | 69 |

Sources: Data from 1924/25 to 1928/29 taken from [7]; from 1929/30 to 1965/66 from [5]; and from 1966/67 to 1971/72 from [6].

parable to the Ayer-Schuh estimates also shown in Table 2, as the latter are based upon a supply elasticity of 0.944 and a demand elasticity of −5.3. If the Ayer-Schuh estimates for zero supply and infinite demand elasticities were shown, the differences between the three estimated benefit streams would be even greater. As can be seen from Table 2, the differences are greatest before 1955 and narrow considerably thereafter.

When internal rates of return are estimated, the differences are equally striking. Using the benefit stream generated by the "optimistic" assumptions, the internal rate of return is only 44 percent in contrast to the 107 percent obtained by Ayer and

Table 2. Estimates of K, K′, costs, and social returns associated with São Paulo's cotton seed research and development program, annual averages, 1924–1967 (thousands of NCr$, 1939 prices)

| Years | K Percent | K′ Percent | Ayer and Schuh Costs | Ayer and Schuh Benefits | New benefit estimates "Optimistic" | New benefit estimates "Pessimistic" |
|---|---|---|---|---|---|---|
| | | | NCr$ | NCr$ | NCr$ | NCr$ |
| 1924–1930 | 0 | 0 | 858 | 0 | 0 | 0 |
| 1931–1935 | 23 | 10 | 5,106 | 38,950 | 12,113 | 3,107 |
| 1936–1945 | 37 | −3 | 10,087 | 210,692 | 56,580 | −30,461 |
| 1946–1955 | 44 | −14 | 13,146 | 259,774 | 20,002 | −210,077 |
| 1956–1966 | 49 | 36 | 12,355 | 334,574 | 209,829 | 209,829 |
| 1967 | 53 | 97 | N.A. | 261,532 | 297,091 | 297,091 |

Schuh using the same supply and demand elasticities. While 44 percent is a comparatively high rate of return, it is only about one-half the lowest estimate contained in Ayer and Schuh's Table 3. If the research station is permitted to impose costs on society as well as benefits, our "pessimistic" set of assumptions, the highest of the multiple internal rates of return, falls to a lowly 2 percent. Yet, even this estimate is overstated, as shown in the next section. These results suggest that what appeared to have been a highly successful venture, may have been, on closer examination, a dismal failure.

## The Partial Equilibrium Nature of the Ayer-Schuh Study

In the Ayer-Schuh study, the only costs considered are direct costs of research and seed multiplication. The authors recognize that "the high rates of return may be an artifact of the analytical framework used for the analysis. For the most part, the analysis was cast in a partial equilibrium frame of reference" [1, p. 567]. But the authors suggest that this may lead to over- or under-estimates of the social rate of return. Although data are not available to test the authors' assertion, it is argued here that the partial equilibrium framework will tend to overestimate the internal rate of return.[2] Moreover, the authors ignored a number of joint inputs whose impact on yields cannot be systematically separated from research results.

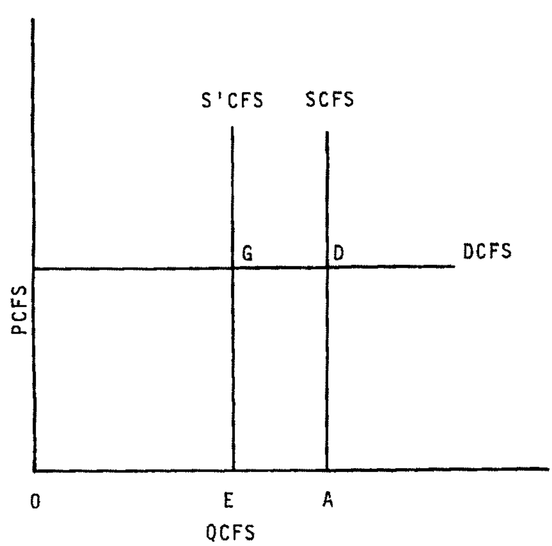


Figure 1. Social returns due to supply shift

1. Increased cotton yields tend to make cotton a relatively more attractive crop, *ceteris paribus*. The introduction of a newer, higher-yielding variety may leave the farming pattern unchanged, but more likely the increased relative attractiveness of cotton production will stimulate resource shifts to cotton. In the process, relative product and factor prices may be altered. The net gain to society, as a result, does not correspond to the gain from increased cotton yields considered alone but to the net increase in total output and the new distribution of factor income, after the ensuing factor adjustments. A programming model of a specific farm or region would show that these resource shifts would reduce the benefits derived solely from partial equilibrium analysis. Moreover, in the case of São Paulo which already has a badly skewed income distribution [3, 4], the Ayer-Schuh results suggest that land holders, or the wealthy class, have captured the majority of the accrued benefits. If the welfare gains accruing to the relatively wealthy groups are weighted less than welfare gains to other groups, as suggested by Bieri, de Janvry, and Schmitz [2, p. 803], then the total gains to society from the technological advance would be less than

[2] The author [8] attempted to use the joint input approach in estimating internal rates of return to research and extension in the cotton-growing areas of Western Tanzania. Farm-level yield data were less precise than in São Paulo, but cost data for the extension and research services were available. The rate of return to research and extension after subtracting out fertilizers and sprays appears to lie in the interval between 20 and 30 percent.

the gains estimated from partial equilibrium analysis.

Both of the above considerations suggest that the Ayer-Schuh estimates are in fact upper boundary estimates.

2. Improved cotton yields derived from experimental station results invariably demand the use of complementary or joint inputs such as new cultural practices, fertilizers, and sprays. Without these joint inputs, yields will be considerably lower. The classical problem of separating the impact of joint inputs thus arises. If all of the yield increases are attributed to one of the joint inputs, the estimated rate of return will be over-estimated. Because of this problem, it seems preferable to consider all of the yield-improving inputs together, i.e., adding the costs of disseminating information to cotton farmers and the costs of sprays and fertilizers to the cost stream or subtracting the cost of these inputs from the benefit stream. The latter procedure would be preferable if one wanted to estimate the returns to research alone. But this approach assumes that the marginal value products of each of the complementary inputs is equal to its price which may not be valid. In any case, the inclusion of these inputs in either the cost or benefit streams will reduce the estimated internal rate of return. Data are not available on the value of sprays and fertilizers applied historically to São Paulo cotton fields, but the Instituto de Economia Agrícola estimates that 4713 metric tons of sprays were applied in 1966 to São Paulo cotton fields versus 2114 in 1959 [6, 137]. The Instituto also estimates that the quantity of fertilizers applied rose 290 percent between 1954 and 1969.[3]

How much the above considerations would lower the internal rate of return is not known, but the 2 percent rate of return estimated for our "pessimistic" case is already close to zero. If the "pessimistic" estimate reflects the true upper boundary limit to the joint inputs producing greater cotton yields, perhaps one should ask, "Why was the rate of return so low?" The answer would seem to be either that the results obtained at the experimental station were not transferred correctly to farmers, or that the results obtained during the first 10 to 15 years were not transferable to farmers. In either case, the validity of Ayer and Schuh's conclusions seems questionable.

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[3] It should be noted that the analytical problem becomes much more complicated if technological progress makes some members of society worse off. This problem is well treated in the recent article by Bieri, de Janvry, and Schmitz [2]. If yield increases result strictly from varietal effects, compensation problems for losers should not arise. However, if producers have in fact received about 60 percent of the social benefits as estimated by Ayer and Schuh, the costs of worsening an already badly skewed income distribution [3, 4] may have to be taken into consideration.

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# SOCIAL RATES OF RETURN AND OTHER ASPECTS OF AGRICULTURAL RESEARCH: THE CASE OF COTTON RESEARCH IN SÃO PAULO, BRAZIL: REPLY

One of the key problems in estimating the rate of return to investments in agricultural R and D is that of measuring induced changes in productivity. The importance of an accurate measure is underscored by Saylor's estimate of a substantially lower internal rate of return to cotton seed R and D in São Paulo than we estimated. Saylor's estimate of productivity change, or the supply shift factor $K$, is based on farm level yield data for the state of São Paulo, while our estimate relies on data generated at experiment stations in the state. For a number of reasons we believe our estimates of the supply shifts of cotton fiber are conceptually appropriate and reasonable, and the estimates of Saylor, based on farm yield data, are not.

## The Appropriateness of Experimental Data

Saylor charges that our estimates of the supply shift factor, $K$, carry a heavy load of upward, experimental bias. Although experimental results normally differ from what would occur under average farming conditions, in the present case several factors reduce the "experimental" bias which might result in generalizing to the state or higher levels. First, only percentage changes in yield and fiber percent, and not the absolute levels, are of interest in the present study, and relative changes under both high and low yield conditions may be expected to be similar.[1] Second, after 1936 test plot comparisons were conducted in all principal cotton growing regions of the state so that variations in geographic and climatic conditions were averaged out. Third, after 1936 comparison tests were conducted at both experiment stations and *Campos de Coopeação*—fields on privately owned and operated farms which were contracted by the state for seed multiplication. The *Campos de Coopeação* provided growing conditions more similar to those of the average farm. Fourth, the applications of fertilizer and insecticides were set at approximately state average levels rather than at output maximizing levels. Fifth, each variety was entered in comparison tests for several years and the results presented are the average. Hence, the effects of weather and other variances are greatly reduced. Sixth, each test plot experiment consisted of several repetitions, which also controlled some of the non-varietal variance. Hence, we would argue that for a number of reasons our estimates of $K$ abstract from at least a major portion of the experimental bias which Saylor suspected. Beyond this, however, we believe his measure of $K$ is inappropriate.

[1] For example, in comparing yields of hybrid seed corn with the open pollenated varieties, plant breeders in the U. S. "expect about the same relative increases in both low- and high-yielding areas" [4, p. 7].

## Saylor's Estimate of Supply Shift

The measure of supply shift, $K$, which Saylor uses to estimate the internal rate of return to São Paulo's cotton breeding program is based on historical farm yield data for the state of São Paulo. For any one particular year Saylor's $K$ is measured as the percentage change in state yield from the average state yield in years 1924/25 through 1927/28—a period during which unimproved varieties were used. This measure possesses several serious drawbacks. First, state yield data during the very early period of cotton production in São Paulo, including 1924/25–1927/28, are of questionable quality. Dr. C. C. Fraga, a long time observer of cotton production and marketing in Brazil and an agricultural economist at the Secretary of Agriculture in São Paulo, makes this point explicit [2, p. 10]. Second, the acreage planted to cotton in Southern Brazil in the early years (mid 1920's to mid 1930's) was extremely small in comparison with the large share of cropped acreage planted to cotton beginning in the early to mid-1930's. The huge expansion in cotton acreage in São Paulo is clearly evident in the data shown in Table 1.

Data on area planted to cotton before 1929 were not encountered, but data on average annual production in São Paulo indicate that between 1926 and 1930 cotton production was less than half the 1932 level [3, p. 82]. After 1938 the acreage fluctuated between a low of 170,000 ha. in 1957 and a high of 730,000 ha. in 1943, but it always remained several times larger than the acreage upon which Saylor's shift factor is based. Certainly it is reasonable to assume that during the early years of limited cotton production the better rather than the poorer quality land was planted, and that the sharp acreage explosion implied the use of land less naturally adapted to cotton production. Again this makes the base period farm data suspect in computing annual changes in yield.

Finally, Saylor's estimates of $K$ are lowest (in fact negative) in the years 1944/45 through 1950/51, and these $K$'s are a major contributor to his low estimates of the internal rate of return. Part of the low state yields during this time likely resulted from a sharp change in relative product prices in favor of coffee starting in 1944. Change in relative price of this important competitor for São Paulo's cropped acreage can be seen in Table 2. Again, the Saylor computation of $K$ does not separate out this source of productivity change.

In summary, we believe our estimates of the productivity shift are good estimates *because* we used the results of carefully conducted experiments, and that the Saylor computations are not based on data which adequately reflect differences in pro-

Table 1. Hectares planted to cotton, São Paulo, 1929–1938

| Year | Acreage | Year | Acreage |
|---|---|---|---|
| 1929 | 6,500 | 1934 | 226,665 |
| 1930 | 11,800 | 1935 | 373,342 |
| 1931 | 37,695 | 1936 | 431,174 |
| 1932 | 49,368 | 1937 | 434,160 |
| 1933 | 130,551 | 1938 | 372,988 |

Source: [2, p. 15].

ductivity that result from varietal change. The key lies in Saylor's statement, "the traditional varieties *apparently* [italics ours] would have outyielded improved varieties . . . in fourteen of the years." Of course, he has no way of knowing, since he did not appeal to experimental results.

## The Partial Equilibrium Framework

Saylor's final major concern is our reliance on partial equilibrium analysis. In the article we recognized this limitation, and it was in part for this reason that the sensitivity analysis was employed. In particular, we agree with Saylor that the distribution of benefits does affect total social welfare and that ideally this should be accounted for in the estimates of the internal rate of return. Perhaps measurement tools and data will someday be available so that such adjustments can be made, but the most we were able to compute were the distribution impacts of the research per se.

Saylor himself provides the reason why more explicit attention was not given to complimentary inputs such as sprays and fertilizers: the data are not available on an historical basis. It should also be noted that although the percentage increases that Saylor cites are large, to the best of our knowledge the base was relatively small, and significant use of these inputs occurred only toward the end of the period covered by our study.

Table 2. Relative prices for cotton and coffee, South Brazil, 1940–1951

| Year | Price Cotton Fiber South Brazil N Cr \$/Ton (Deflated) | Price of Coffee South Brazil N Cr \$/60 Kg (Deflated) |
|---|---|---|
| 1940 | 3.17 | .08 |
| 1941 | 2.59 | .08 |
| 1942 | 3.02 | .08 |
| 1943 | 3.52 | .08 |
| 1944 | 3.38 | .15 |
| 1945 | 2.96 | .16 |
| 1946 | 4.10 | .18 |
| 1947 | 3.92 | .15 |
| 1948 | 4.16 | .15 |
| 1949 | 4.16 | .18 |
| 1950 | 4.71 | .30 |
| 1951 | 6.29 | .27 |

Source: [1, p. 196].

Taking more strict account of the complimentary inputs would be comparable to lowering our estimate of $K$. Our sensitivity analysis suggests that lowering $K$ by 10 percent will lower the rate of return by some 3 percentage points. Further reductions would have the same order of effect. For example, using our elasticity estimates of $-5.3$ for demand and .94 for supply and decreasing all $K$'s by 40 percen lowers the internal rate of return to 74 percent from 89 percent at $K$ nominal—still a very high rate.

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# SOCIAL RATES OF RETURN AND OTHER ASPECTS OF AGRICULTURAL RESEARCH: THE CASE OF COTTON RESEARCH IN SÃO PAULO, BRAZIL: COMMENT*

The high internal rate of return computed by Ayer and Schuh [1] for the cotton research program is due to the neglecting of some essential aspects of modern economic theory. The authors assume an aggregated demand curve for cotton fiber, whose area integral reflects gross social utility at any given quantity of cotton. The area below the aggregated demand curve indicates gross social utility only if it is modified in the Hicksian sense (see, for example, [2, p. 747 ff.]).

The curve $D_2(x)$ in Figure 1 is obtained from the aggregated demand curve $D_1(x)$ by subtracting from $D_1(x)$ an amount $B(x)$ for every $x$ except $x = 0$. $B(x)$ for every $x$ is that amount at which an average individual demander changes his demand for $x$ in preference for another commodity caused by changes of price relations at any given income. $D_1(x)$ is identical with $D_2(x)$ only if the income effect of the changing price relations is zero. The area integral below $D_2(x)$ is less than that below $D_1(x)$ for any $x$. The gross social returns are also less than those computed by Ayer and Schuh, but the consequences for the internal rate of return are *prima facie* the same. Therefore the social advantage of the Brazilian cotton research program seems to be overestimated.

## Problems in Cost Calculation

For similar reasons the method used by Ayer and Schuh in computing costs as the area below $S(x)$ between 0 and $x$ also seems doubtful (cf. [3]). Assuming that the factor markets are in equilibrium, the attainable alternative income (opportunity costs) of inputs used for the production of $\bar{x}$ is indicated by the area $OHBP_1$ and correspondingly for the production of $\bar{\bar{x}}$ $OAEP_1$ (Figure 2). Ayer and Schuh's computation of the social returns is as follows:

$$\int_0^{\bar{x}} D(x)\,dx - \int_0^{\bar{x}} S^{(1)}(x)\,dx - \int_0^{\bar{\bar{x}}} D(x)\,dx + \int_0^{\bar{\bar{x}}} S^{(2)}(x)\,dx = OEFGH - OBH.$$

However, corrected social return now is

$$R = \int_0^{\bar{x}} D(x)\,dx - OHBP_1 - \int_0^{\bar{\bar{x}}} D(x)\,dx + OAEP_1 = AFGH + OAEP_1 - OHBP_1.$$

The social costs of the specific research and development program are underestimated by the nominal costs approach used by the authors because opportunity costs of the research resources were ignored. For a proper solution resources employed in cotton research programs must be evaluated with regard to their best alternative use. This means that the supply curve of improved cotton fiber must be shifted to the left.

To sum up, the social rate of return has to be modified twice. First, a specification of aggregate demand in the Hicksian sense causes a decrease of gross social returns; second, the choice of social-opportunity-cost-approach alters the area to subtract. The net social returns as the difference of the area integrals below modified demand and supply curves are less than those theoretically anticipated and correspondingly computed by Ayer and Schuh. A quantification of the internal rate of return is not given here, but it is below that rate they computed.

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* The author is indebted to Professor U. Koester for many helpful suggestions.

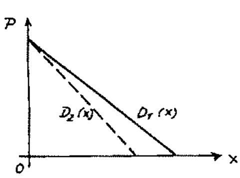


Figure 1

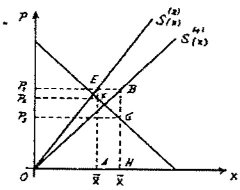


Figure 2

## References

[1] AYER, HARRY W., AND G. EDWARD SCHUH, "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in São Paulo, Brazil," *Am. J. Agr. Econ.* 54:557–569, Nov. 1972.

[2] CURRIE, J. M., J. A. MURPHY, AND A. SCHMITZ, "The Concept of Economic Surplus and its Use in Economic Analysis," *Econ. J.* 81:741–799, Dec. 1971.

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SOCIAL RATES OF RETURN AND OTHER ASPECTS OF AGRICULTURAL RESEARCH: THE CASE OF COTTON RESEARCH IN SÃO PAULO, BRAZIL: REPLY

The tools of project evaluation and welfare analysis are still quite blunt. Controversy still rages over conceptual issues, and measurement problems are great, especially since one has to infer so much from the data, and since in order to make precise estimates, one generally has to know a great deal more about an economy and how it works than we typically have at hand.

These caveats aside, we would take issue with both of Bönig's major points, even though in one case an appropriate issue has been raised. In that case, however, neither his diagnosis of the problem nor its solution appear to us to be correct. Let us take each of the issues in turn.

## The Compensation of the Demand Curve

Welfare analysis of the kind undertaken in our paper always involves a question of which demand curve is relevant. This choice has to be resolved in terms of the problem at hand. For some problems a compensated demand curve is appropriate; for others, an uncompensated demand curve is appropriate.

What Bönig seems to have missed in our analysis is that we are not working with the demand curve for a final product. Rather, we are working with the demand curve for cotton fiber, which in this case is a derived demand curve. Income does not enter this demand equation, and hence the question of *income* compensation of the demand equation is not relevant.

Even if our analysis had conceptualized the demand for cotton fiber as final demand, however, Bönig's analysis of the use of an ordinary demand curve (*ODC*) overstates the amount of bias, and under the conditions of the present problem, it is likely that the bias from failing to use a Hicksian compensated demand curve (*HCDC*) would be small. The logic (and shortcoming) of his criticism may be derived with the aid of Figure 1.[1] Assume an initial price of $P_0$ with budget restraint $\overline{P}_0$ tangent to indifference curve $I_0$ at $A$. At this price no cotton fiber is demanded, as indicated at point $A$ in the upper figure and $P_0$ in the lower figure. If the price of cotton fiber is lowered (by a technology induced supply shift) to $P_1$, the new budget constraint $\overline{P}_1$ is tangent to the higher indifference curve $I_1$ at $C$ and determines the quantity demanded $D$. By continuing to vary price, an ordinary demand curve is generated and is depicted as *ODC* in the lower graph.

The "value" to the producer of being able to buy

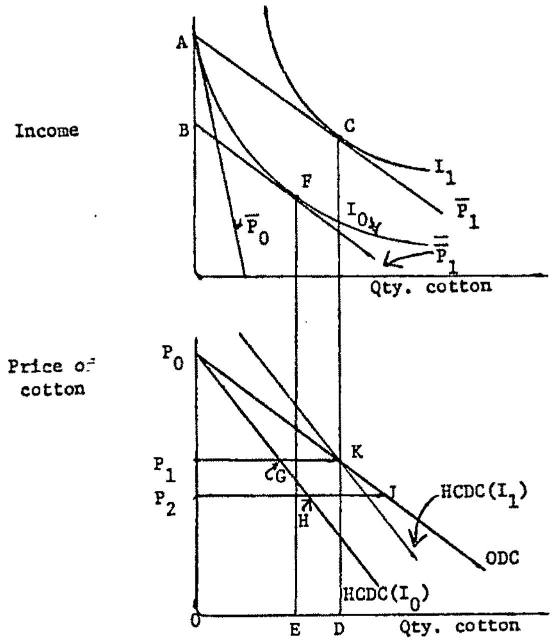


Figure 1. Derivation of the Ordinary and Compensate Demand Curve

any quantity he desires at new price $P_1$ instead of at $P_0$ is the distance $AB$ in the top graph. That is, the consumer of cotton fiber would be willing to pay $AB$ and would still be left in his initial "welfare condition" following the change in price if he is free to buy any quantity of the commodity at the new price. Since he does not pay $AB$, he gains a surplus which is referred to by Hicks [3] as "compensating variation," and it is this surplus which is the quantity in question here. Operationally, it is usually easiest to measure this surplus not by $AB$, but by an equivalent amount represented by the area under the Hicksian Compensated Demand Curve and above the price line.[2] Thus, when the compensating amount $AB$ is taken into account, the amount demanded at $P_1$ is determined at point $F$ in the upper graph and equals $OE$ in the lower graph. By varying prices and adjusting for the compensation required to keep the consumer of cotton on the original indifference curve, the Hicksian compensated demand curve is derived. If the price were to drop from $P_1$ to $P_2$, and if the consumer had already paid compensation and was consuming at $G$, the net consumer surplus resulting from the price change would be $P_2HGP_1$ in the

[1] An excellent review of the theoretical constructs employed here is given in Currie, Murphy, and Schmitz [2].

[2] That the surplus $AB$ is equal to the area above the price line and below the Hicksian Compensated Demand Curve ($AB$ = area $P_1GP_0$) has been demonstrated by Hicks [3] and Patinkin [4].

bottom graph. This area is of course smaller than the surplus which would be estimated using the *ODC*—area $P_2JKP_1$.

Three factors would diminish if not eliminate the bias charged by Bönig in the cotton study—had demand been conceptualized as final demand. First, consumers of cotton fiber have not in fact paid compensation and are not consuming cotton at *G*. Rather, no compensation was being paid, and consumption was at *K*. Given this, the appropriate *HCDC* passes not through $P_0$ as indicated in Figure 1 and by Bönig, but through point *K*. Clearly the bias is reduced.

A second factor reducing bias of the estimate of net social benefits, and in this case the consumer surplus portion of net social benefit, is the elasticity of demand. If demand were perfectly elastic, there would be no consumer surplus to begin with—only producer surplus—and hence no bias. *Ceteris paribus,* the greater the elasticity, the less the bias induced by using an *ODC* instead of a *HCDC* to estimate consumer surplus. In the case of Brazilian cotton, the demand is very elastic (our estimate was $E_d = -5.3$) if not perfectly elastic because Brazilian exports have been a relatively small fraction of the world market.

Finally, as Hicks [3] notes, "in order that the Marshall measure of consumer's surplus should be a good measure, one thing alone is needed—that the income effect should be small." If that is the case, the indifference curves are parallel, at any quantity of the commodity and the *ODC* and *HCDC* coincide. In the present case, the income elasticity of demand for cotton cloth is relatively low—our estimate for Brazil during the period under analysis is approximately .6 [1, p. 115]. Hence, it is likely that the income effect would be relatively small.

## Problems in Cost Calculation

Bönig's analysis on the supply side strikes us as being just plain wrong. In the partial equilibrium framework, within which our analysis was cast, the opportunity costs are measured by the area under the supply curve (Ayer-Schuh) and not by the area subtended by the supply curve (Bönig). An exception, of course, is where the buyer is a monopsonist, in which case his incremental costs are given by the curve marginal to the market supply curve. That is clearly not the case here, however.

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## RESOURCE INVESTMENTS, IMPACT DISTRIBUTION, AND EVALUATION CONCEPTS: COMMENT

The article by Robert Kalter and Thomas Stevens [1] discussed here is a pioneering effort to deal empirically with problems of income distribution arising from federal investments in resource development projects (and indeed for any type of governmental investment). Kalter and Stevens (hereinafter K-S) are to be commended for their efforts to grapple with a problem which economists have long neglected. However, the K-S contribution contains a number of errors requiring correction if practical implementation of their model is to be given serious consideration.

K-S develop several equations designed to account for the incidence to identifiable groups of net benefits from federal investments [1, pp. 208–209]. The critique of the K-S model can be facilitated by considering the following simplifications of the equations actually developed by the authors. In the interests of clarity the equations will be expressed in present value terms except where noted. Consider the first basic identity:

$$NB_j = GB_j - C_j \tag{1}$$

where

$NB_j =$ present discounted value of net benefits to class $j$,
$GB_j =$ present discounted value of gross benefits to class $j$,
$C_j =$ present discounted value of costs to group $j$.

K-S find it useful to break up the cost components as depicted in the following equation:

$$C_j = (Z_j + R_j + O_j) \tag{2}$$

where

$Z_j =$ portion of tax payment by class $j$ that is allocated to the project or investment,
$R_j =$ direct reimbursement or repayment by class $j$ to the government,
$O_j =$ operation and maintenance costs to class $j$.

The authors then introduce the notion of a "reimbursement adjustment." They argue, correctly, that the difference between the actual repayment or reimbursement by class $j$ and the reimbursement that class $j$ would have paid had that reimbursement been proportional to the "appropriate tax structure" represents a redistribution of income that must be accounted for. The following equation combines equations (1) and (2) and includes the K-S "reimbursement adjustment":

$$NB_j = GB_j - [Z_j + (A_j - P_j) + O_j] \tag{3}$$

where

$A_j =$ the actual reimbursement or repayment by class $j$,
$P_j =$ the reimbursement or repayment that would be made by class $j$ had the repayment schedule been proportional to the appropriate tax structure.

An initial and easily correctable error arises from the authors' assumption that annual operation and maintenance costs will either be paid for by the project beneficiaries in full or will be completely paid by the government [1, p. 208]. They argue, however, that the results of the analysis will be the same irrespective of which assumption is adopted. It seems clear that net benefits to a given group will be smaller the larger the amount of operation and maintenance costs assigned to that group. It is also true that the proportion of operation and maintenance costs borne directly by project beneficiaries varies widely between projects. Consequently, there is no reason why operation and maintenance costs should be conceptually different from other types of costs. If they are borne directly by project beneficiaries they should be subjected to the same sorts of analyses as other types of reimbursable costs. Therefore, equation (3) must first be modified to take account of this fact. The $O_j$ term is thus eliminated and reimbursable operation, and maintenance costs are included in the $A_j$ term while the nonreimbursable costs will be included in the $Z_j$ term. With this correction the basic equation becomes

$$NB_j = GB_j - (Z_j + A_j - P_j). \tag{4}$$

Consider now a federal investment which benefits the nation as a whole (as opposed to some region). If dynamic distributional effects arising from differing marginal propensities to consume and save are assumed to be negligible, it is true that the net national benefit attributable to the federal investment will remain constant irrespective of who pays what portion of the cost and irrespective of the method of payment (be it taxes or direct repayment).[1] It is also obvious that both gross benefits and costs to the nation will also remain constant irrespective of the methods of financing and the incidence of those benefits and costs. The argument may be clarified by considering the following definitions,

$$\bar{k} = \sum_{j=1}^{J} NB_j \tag{5}$$

[1] This assumption, while not explicitly alluded to by K-S, is at least implicit in both their theoretical formulation and in the subsequent empirical examples.

$$\bar{m} = \sum_{j=1}^{J} GB_j \tag{6}$$

$$\bar{n} = \sum_{j=1}^{J} Z_j + \sum_{j=1}^{J} A_j \tag{7}$$

where $\bar{n}$, $\bar{m}$, and $\bar{k}$ are all constants, and the incidence falls on $J$ arbitrarily defined classes.

The definition in (7) merely indicates that total costs include the sum of all increased tax payments occasioned by the decision to undertake the investment (assuming a flexible federal budget constraint) plus the additional costs paid in the form of direct reimbursement or repayment.

The principal difficulty with the K-S formulation stems from the misspecification of the reimbursement adjustment. If $q$ is defined to be $\sum_{j=1}^{J} P_j$, then equation (4) may be rewritten as follows:

$$\bar{k} = \bar{m} - [\bar{n} - q]. \tag{8}$$

It must always be true that the sum of the direct reimbursement will equal the sum of the additional taxes that would have been paid had the reimbursement been proportional to the appropriate tax structure. However, since there are an infinite number of combinations of tax and direct reimbursement schemes, the $\sum_{j=1}^{J} A_j$ can vary and, of course, $\sum_{j=1}^{J} P_j$ varies with it. The result is that the $q$ term on the right side of the equation is a variable while every other term in the equation is a constant. This, of course, is mathematically nonsensical.

Still, it might be tempting to suggest that the sum of the net benefits to the nation is, in fact, not constant although total gross benefits and total costs are. This line of argument suggests two conclusions. First, the total net benefits attributable to the project will vary with the amount of reimbursement. Second, the larger the amount of direct reimbursement the greater the net benefits. This latter conclusion is easily seen since as the proportion of costs borne as reimbursement increase, variable $q$ increases, while $\bar{m}$ and $\bar{n}$ remain the same. Consequently, as $q$ increases, $k$ must also increase. To accept this line of reasoning is to accept the notion that the total net benefits from a project increase as the method of financing is shifted away from tax financing and toward direct reimbursement or repayment. Net benefits, then, will be maximized if the investment is financed solely by direct repayment and no additional tax revenues are utilized.

The error in the K-S formulation can be seen by postulating a situation in which the investment is totally repaid by the citizenry through a direct repayment schedule in which each *group's* payments are exactly equal to the payment which that group would have made had the project been tax financed. In this case the investment would entail no national cost whatsoever and the benefits of it would rain upon the citizenry as manna from the sky. In spite of K-S there is no reason to suspect that schemes of cost allocation and investment repayment are going to produce free lunches. Their basic equation obviously requires correction.

The beneficiaries of any federal investment pay for it through some combination of taxes and direct charges. It is true that to the extent the schedule of beneficiary charges differs from the tax schedule, some change in the distribution of income will occur. However, this change must be accounted for *separately* from the actual costs paid. Equation (4), then, may be correctly specified as follows:

$$NB_j = GB_j - [Z_j + A_j + (A_j - P_j)]. \tag{9}$$

If $(\sum_{j=1}^{J} A_j - \sum_{j=1}^{J} P_j)$ is defined as $r$ and substituted for $q$ in equation (8), the difficulty is overcome since $r$ must always be equal to zero. This correction, then, accounts for the fact that the sum of all costs and benefits across national income classes must be constant irrespective of the distribution of those costs and benefits.

K-S do respecify the $Z_j$ term for use in situations where the benefits accrue solely to a region [1, p. 209]. In this case it is true that the net benefits will vary depending upon the method of financing. Regional beneficiaries will receive a larger sum of benefits if the costs are borne by the nation as a whole through the general tax structure than if they are borne primarily through direct repayment by regional beneficiaries. However, this variance may be adequately accounted for in the respecification and the above correction is in no way altered.

A third difficulty with the K-S specification is an error of omission. The authors should have been careful to note that the reimbursement adjustment is appropriately applied only in those cases where the reimbursement is charged as a flat cost to the beneficiaries of the investment rather than as a variable charge per unit of output. In the first case the marginal cost per unit of output is zero whereas in the second the reimbursement by the beneficiary depends entirely on the quantity he consumes.

K-S may be faulted on a number of other grounds. They fail to state explicitly that any definition of neutrality is inherently a value judgment and that proportional distribution, for example, is not necessarily more neutral than equal absolute distribution. K-S should also have formulated their basic equation in a fashion which would enable the analyst to take

explicit account of the distribution of income with and without the investment in question. Changes in distribution can be properly analyzed only with reference to the distributions prevailing both with and without the investment.

The work of Kalter and Stevens, as corrected, represents a useful first step toward development of procedures to account for distributive consequences of federal investments. Much work remains to be done in this area, however, and it is to be hoped that economists will increasingly involve themselves in this heretofore neglected field.

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[1] KALTER, ROBERT J., AND THOMAS H. STEVENS, "Resource Investments, Impact Distribution, and Evaluation Concepts," *Am. J. Agr. Econ.* 53:206–215, May 1971.

## RESOURCE INVESTMENTS, IMPACT DISTRIBUTION, AND EVALUATION CONCEPTS: REPLY

The comment by H. J. Vaux [3] raises three major and several minor criticisms of the Kalter-Stevens (hereafter K-S) income distribution impact model [1]. In addition, Vaux offers suggested modifications to the model to meet his objections. If we have properly interpreted the comment, his position was derived by failing to understand the essence of our model specification. Consequently, the suggested modifications are unnecessary and, in fact, lead to conceptual errors. In one case, this results in the double counting of cost. This reply is directed toward these issues.

First, the original K-S model included a simplifying assumption, not an error as stated by Vaux, that the annual operating and maintenance cost of a proposed government investment would be paid in full by either project beneficiaries or by the government. In fact, this is often the situation. We stated that the *analysis*, not the *results* of the analysis (apparently Vaux's interpretation), would be the same in either case [1, footnote 8]. In other words, the model used for evaluation would be specified identically in either case. Empirically, the data would obviously differ. This is reflected in both our model specification (which includes operation and maintenance costs) and its implementation in the case study reported.

Vaux should note that our equation (4) refers to a specific distributional group and treats annual costs explicitly. We chose not to treat a mixed case—one where a portion of operating costs are paid directly and a portion are not—for purposes of simplicity, but the model can be easily modified to account for such situations. In either case, the distributional impacts of annual costs should be handled as a separate factor from investment costs (as in K-S) because they do not represent an expenditure by society which is reimbursed over time. Consequently, a reimbursement adjustment, which takes account of the loan nature of a transaction as well as the distributional impacts, is unnecessary and incorrect.

Vaux's confusion on the loan concept is apparently at least partially responsible for his second criticism. His discussion, however, is sufficiently unclear to lead to several interpretations. He argues that, under the K-S formulation, net national benefits attributable to a single federal investment can be variable depending upon the amount of reimbursement. As an example, he argues that if investment costs are totally reimbursed with the same incidence as the original tax structure, no national cost will be entailed. This is obviously incorrect and, properly interpreted, the K-S model does not lead to this result.

The hypothetical case shown in Table 1, along with formula 1, can clarify the situation. The case is that posed by Vaux where reimbursement is total and proportional to the original tax structure. Formula 1 represents the basic identity resulting from an aggregation of the K-S distributional equations for each class.

(1) Net Benefits

$$= \sum_{j=1}^{J} B_j - \Big[\sum_{j=1}^{J} Z_j + \Big(\sum_{j=1}^{J} A_j - \sum_{j=1}^{J} P\Big) + \sum_{j=1}^{J} 0_j\Big]$$

where 0 represents annual costs and the remaining symbols are as indicated in Table 1.

The term $\sum_{j=1}^{J} A_j - \sum_{j=1}^{J} P_j$ represents the aggregated "reimbursement adjustment." This adjustment is necessary because initial project investment, where reimbursement is involved, represents a loan by society to specific groups within it. The loan, or a portion of it, must be repaid over time. In the hypothetical example, the national cost of 60 is initially a federal cost ($Z$) which is repaid over time ($A$). The "adjustment" accounts for any deviations from the tax structure in repayment and permits partial reimbursement situations to be handled. Since $A$ always equals $P$ in the aggregate, the result is that federal costs are always reduced by the amount of reimbursement, but national ef-

**Table 1. Hypothetical investment situation**

| Distributional class ($j$)[a] | $Z$[b] | $B$[c] | $A$[d] | $P$[e] |
|---|---|---|---|---|
| 1 | 10 | 20 | 10 | 10 |
| 2 | 20 | 30 | 20 | 20 |
| 3 | 30 | 20 | 30 | 30 |
| $\sum_{j=1}^{J}$ | 60 | 70 | 60 | 60 |

[a] $J$ = distribution classes ($j$ = 1, 2, 3).
[b] $Z$ = tax revenue used to finance project on present value basis.
[c] $B$ = gross benefits on present value basis.
[d] $A$ = actual reimbursement on present value basis.
[e] $P$ = reimbursement, if proportional to original tax structure, on a present value basis.

ficiency costs remain constant. When used for *specific* distributional classes, the original K-S formula (4), then, permits an evaluation of class distributional effects without understating overall national efficiency costs. The reimbursement adjustment automatically accounts for loan repayment.

Vaux appears either to have misunderstood the loan concept or confused the aggregate identity with the formulas relating to specific distributional classes. The first point was covered in footnote 9 [1, p. 208] of the original article and can be easily followed by substituting the aggregate values from Table 1 into equation (1) and into our original equation (4) for each distributional class. Vaux's equation (7) misses this concept entirely. When he states that "the sum of the direct reimbursement will equal the sum of the *additional taxes* [italics ours] that would have been paid," Vaux is double counting. The K-S formulation assumes reimbursement repays a loan and not that it is comparable to an added tax burden on specific groups.

In addition, Vaux's formulation of the K-S model is internally inconsistent and, therefore, incorrect from another standpoint. He states that *only q* in his equation (8) can be variable, and since this term appears on the right side of the equation, the result is nonsensical. We would agree. The problem is that Vaux ignores his own discussion in the same paragraph which stated that his $\sum_{j=1}^{J} A_j$ can also be a variable. Since this term makes up part of his $\bar{n}$ term, and when $q$ varies, $\sum_{j=1}^{J} A_j$ must vary by an equal amount, the mathematical integrity of the identity is maintained. The only way that Vaux could have fallen into such an obvious error is to have confused a portion of the aggregate identity (across all classes) with the K-S equation for separate distributional classes. In that formulation, however, the net benefits to a class are a variable and depend on reimbursement policy. This does not mean that total net benefits from a project can vary. Unfortunately, there is no "manna from heaven" even though Vaux has tried hard to create it.

Vaux's confusion might be dismissed as an oversight if it were not for his suggested modification of the K-S formulation. He formulates equation (9) which refers to a specific distributional class and contains the $A_j$ term twice on the right side. Using this approach to evaluating our formulation, we have shown the resulting identity for all classes as equation (2).

(2) Net Benefits

$$= \sum_{j=1}^{J} B_j - \Big[\sum_{j=1}^{J} Z_j + \sum_{j=1}^{J} A_j + \Big(\sum_{j=1}^{J} A_j - \sum_{j=1}^{J} P_j\Big)\Big].$$

Obviously, the Vaux approach results in double counting actual reimbursement costs. Vaux would have us believe that net national benefits vary because of reimbursement policy. This is the same error he incorrectly states is contained in the K-S formulation.

Third, Vaux states that the reimbursement adjustment can be applied only in those cases where repayment is charged as a flat cost to the beneficiaries rather than as a variable charge per unit of output. The reason for this statement is unclear. However, it is (given the K-S approach) an empirical, not a conceptual problem. If data is available to compute properly the actual reimbursement figure for our original equation (4), no problem exists.

Finally, Vaux indicates that a with-without comparison is required to account properly for distribution changes and that the K-S does not account for this We agree completely with the suggestion and stated as much at the outset of our original model discussion [1, p. 207]. In subsequent work, we have made this point even more explicit [2].

We are pleased at the continued interest being generated by our 1971 article since applied work in the area of distributive impacts has often been ignored by the profession. We would hope that useful extensions for this type of evaluation will be forthcoming. Unfortunately, Vaux's comment does little to meet the need.

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# WELFARE ANALYSIS OF THE VOLUNTARY CORN DIVERSION PROGRAM: SUPPLEMENTARY EQUATIONS AND PROJECTIONS*

In a recent paper analyzing the welfare effects of the Voluntary Corn Diversion Program, 1961 to 1966, the conclusions from a supply analysis of corn covering 1919 to 1966 were presented and used in the analysis [2, pp. 178–9]. There is currently much uncertainty on what will happen to the production of various agricultural commodities under a changing price and commercial policy structure. The purpose of this communication is to extend the supply analysis to project corn acreage harvested for grain over the 1966 to 1973 period under the assumption of no production controls on corn and to draw implications for supply response during 1974 to 1976.

The basic conclusion of the original analysis was that the acreage control features of the corn programs had little long-run impact on corn acreage harvested for grain. It was further concluded that free market acreage of corn harvested for grain would have been about 60 million acres during 1961–66 at then prevailing prices. The response of corn acreage since 1966 appears to support these conclusions.

Few background details were provided in the recent paper, so this communication provides some. The land supply equations for corn used for projections are presented in the next section. In the second section the projections are presented. Implications for corn acreage harvested for grain during 1974–76 are discussed in the final section.

## Predicting Equations

Of the land supply equations for corn originally estimated, the two equations estimated using data from 1919 to 1937,[1] which best appear to predict corn acreage harvested for grain into the 1970's, are

$$(1)\quad \operatorname{Log} A = \underset{(3.75)}{3.96} + \underset{(0.141)}{0.230}\ \operatorname{Log} P_{1t-1} - \underset{(0.256)}{0.651}\ \operatorname{Log} P_{2t-1} + \underset{(0.347)}{0.508}\ \operatorname{Log} P_w + \underset{(0.615)}{0.364}\ \operatorname{Log} P_c - \underset{(0.008)}{0.021t}$$

$$R^2 = 0.55,$$

and

$$(2)\quad \operatorname{Log} A = \underset{(3.42)}{2.45} + \underset{(0.226)}{0.464}\ \operatorname{Log} P_{1s} - \underset{(0.445)}{1.115}\ \operatorname{Log} P_{2s} + \underset{(0.347)}{0.941}\ \operatorname{Log} P_w + \underset{(0.545)}{0.736}\ \operatorname{Log} P_c - \underset{(0.009)}{0.029t}$$

$$R^2 = 0.53.$$

The standard errors of each coefficient are in parentheses, and

$A$ = acres of corn harvested for grain (millions),
$P_{1t-1}$ = deflated average price of corn received by farmers, lagged one year (cents per bushel),
$P_{1s}$ = $0.5\,P_{1t-1} + 0.3\,P_{1t-2} + 0.2\,P_{1t-3}$,
$P_{2t-1}$ = deflated index of prices received by farmers for other crops, lagged one year (cents per unit),
$P_{2s}$ = $0.5\,P_{2t-1} + 0.3\,P_{2t-2} + 0.2\,P_{2t-3}$,
$P_w$ = deflated farm wage rate, without room or board (cents per hour),
$P_c$ = deflated index of the price of capital (cents per unit),

and

$t$ = time trend (last two digits of the year).

All data are derived from USDA published data by crop year. All prices are deflated by the index of prices paid by farmers, 1910–14 = 100. The other crop price aggregate is computed as

$$(3)\qquad I_2 = \frac{I - w_1 I_1}{w_2}$$

where $I$, $I_1$, and $I_2$ are indexes of prices received for all crops, corn, and other crops, respectively, 1910–14 = 100, July 1 to June 30 crop year. The weights, $w_1$ and $w_2$, are the value shares of corn and other crops, respectively, $w_1 + w_2 = 1$. The index, $I_2$, is deflated to obtain $P_2$.

The nominal price index of capital for 1919–37 is

$$(4.1)\qquad \begin{aligned} I_c = {} & 0.283\ I(\text{Motor Supplies}) \\ & + 0.283\ I(\text{Motor Vehicles}) \\ & + 0.243\ I(\text{Farm Machinery}) \\ & + 0.139\ I(\text{Fertilizer}) \\ & + 0.051\ I(\text{Seeds}), \end{aligned}$$

and for 1938–73 is

* Helpful suggestions and comments were received from D. G. Johnson, F. E. Walker, W. Barr, T. F. Glover, and an anonymous reviewer of this journal.

[1] In the original analysis [1], land supply equations were estimated for a variety of time periods in the 1919–66 interval. The predictions based on equations for all other time periods are less than actual acreages harvested after 1960. However, the 1919–1937 interval is the only extended time period since 1919 for which there were no land restrictions.

$$(4.2) \quad I_c = 0.266\ I(\text{Motor Supplies}) + 0.266\ I(\text{Motor Vehicles}) + 0.228\ I(\text{Farm Machinery}) + 0.156\ I(\text{Fertilizer}) + 0.084\ I(\text{Seeds}).$$

The weights are average value share weights for each period.[2] The $I_c$ are then deflated to obtain $P_c$.

These equations are subject to several statistical criticisms, e.g., multicollinearity, simultaneous equations bias, and relatively low $R^2$. However, the objective is to examine the predictive capability of the equations and not their statistical problems.[3]

The predicting equations are in Log-Log form, so the coefficients are elasticities. The signs of all coefficients are theoretically consistent.[4] The magnitudes of the cross-price elasticity of acres harvested with respect to other crop price appear large, but are feasible values.[5] Equation (1) is a short-run (one year) adjustment equation using prices lagged one year. Equation (2) is a three to five year adjustment equation using a weighted average of lagged prices for three years.

## Results

Acres of corn harvested for grain predicted by equations (1) and (2) along with actual acres planted and acres harvested for grain are presented in Table 1. The corresponding price series for 1966–73 are presented in Table 2. In setting the stage for 1973 and beyond, it is instructive to examine the predicted versus actual results for 1966 to 1972. First, if the acreage control programs are effective in restricting corn acreage in the short run, then the short run predictions of equation (1) should be close to actual acres harvested during years when production was encouraged (or when restrictive measures were reduced). The predictions of equation (1) closely approximate actual acreages for 1967, 1971, and 1972, while production was encouraged in 1967 and 1971. Second, the corn program appears to have been effective in reducing corn acreage during 1968–70. Third, the real price series for corn and other crops indicates that the relatively high acreages of corn predicted by both equations for 1970 and 1971 are due to the decline in other crop prices, which reached a bottom in 1970, and not to corn prices. Finally, the predictions of equation (2) are expected acreages after a free market has been in operation for three to five years. For example, if all controls had been removed at the beginning of the 1971 crop year and the then prevailing real prices had continued, we could have expected acres harvested for corn to reach about 72 million acres by 1974–76.

However, the corn program was still in existence through early 1973 and the price structure had changed. In particular, the aggregate price index of other crops rose relative to the price of corn during 1971–72. The three 1973 acreage predictions are based on the following price projections. Two

Table 1. Actual and predicted corn acres (millions)

| | Acres Planted | Acres Harvested For Grain | | |
|---|---|---|---|---|
| | | | Predicted | |
| | | Actual | (1) | (2) |
| 1938–40 | 91.6 | 79.8 | 77.8 | 80.1 |
| 1954–55 | 81.6 | 68.6 | 65.1 | 67.5 |
| 1961–65 | 66.2 | 57.5 | 58.4 | 59.8 |
| 1966 | 66.3 | 57.0 | 58.3 | 59.4 |
| 1967 | 71.1 | 60.7 | 60.6 | 64.0 |
| 1968 | 65.1 | 56.0 | 59.7 | 64.2 |
| 1969 | 64.3 | 54.6 | 60.0 | 64.0 |
| 1970 | 66.8 | 57.4 | 63.4 | 67.4 |
| 1971 | 74.1 | 64.0 | 65.8 | 71.8 |
| 1972 | 66.8 | 57.3 | 57.2 | 66.1 |
| 1973 (1) | 72.4[a] | 62.5[a] | 58.8 | 64.9 |
| (2) | | | 59.5 | 66.5 |
| (3) | | | 61.6 | 68.4 |

[a] July estimate.

Table 2 Deflated price series used in predictions (cents)

| | $P_{1t-1}$ | $P_{1s}$ | $P_{2t-1}$ | $P_{2s}$ | $P_{w}$ | $P_c$ |
|---|---|---|---|---|---|---|
| 1966 | 36 | 36 | 77 | 79 | 37 | 96 |
| 1967 | 37 | 37 | 74 | 76 | 39 | 96 |
| 1968 | 30 | 33 | 72 | 74 | 41 | 97 |
| 1969 | 30 | 31 | 69 | 71 | 42 | 95 |
| 1970 | 31 | 31 | 62 | 66 | 42 | 95 |
| 1971 | 34 | 32 | 59 | 62 | 42 | 96 |
| 1972 | 26 | 29 | 64 | 62 | 42 | 95 |
| 1973 (1) | 32 | 31 | 64 | 63 | 43 | 92 |
| (2) | 32 | 31 | 64 | 63 | 43 | 95 |
| (3) | 37 | 33 | 64 | 63 | 43 | 95 |

[2] The value share weights in equation (4.2) are those used originally for the 1938–66 period and have not been updated for this note.

[3] A detailed discussion of the statistical analysis can be found in [1, Chapter III].

[4] The theoretical signs of the factor price coefficients are indeterminate. They reflect a combination of factor supply and substitution in production relationships. The positive coefficients reflect, in part, the net substitution between land and labor or capital. In a time series analysis, the coefficients may also reflect trends, either reinforcing or offsetting the time trend coefficient.

[5] Using several equations from other time periods in addition to equations (1) and (2), the cross-price elasticity was estimated at 0.7 of the absolute magnitude of the own-price elasticity in the original analysis [2, p. 179]. That estimate is low. Equations (1) and (2), which have stood the test of time, imply that the cross-price elasticity is 2–3 times as large as the own-price elasticity of supply.

deflated corn prices lagged one year are used. The price of 32 in Table 2 corresponds to a nominal price of $1.40 per bushel in the 1972 crop year, 37 to $1.80. The nominal price of corn averaged about $1.60 per bushel for the 1972 crop year. The price of other crops computed from equation (3) indicates that the 1972 real price equals that for 1971. However, the deflated index of prices received by farmers for other crops at 64 may be underestimated, and if so, will bias the predicted corn acreage upward.

The real wage rate of 43 corresponds to a nominal wage of $2.03. This was projected on the basis of the index of prices paid for labor from the last published wage rate of $1.73 in 1971. The capital price index yields a real price index of capital of 92. The price index of 95 projects the 1972 real index to 1973. If this index is too low, the projected acreages are biased downward.

The predictions of equation (1) range from 58.8 to 61.6 million acres in 1973, those of equation (2) from 64.9 to 68.4. Using prediction (2) as the best estimate, the corn acreage harvested for grain range would be 59.6 to 66.5 million acres. Since corn program restrictions were reduced in 1971, farmers have probably made some longer-run adjustments, as evidenced by the July 1 estimated harvested for grain acreage of 62.5 million acres.

## Implications for 1974–76

This section is limited to a discussion of changes in corn acreage harvested for grain during 1974–76 implied by real price and time changes, using 1973 predictions as the base. Acreage predictions are not made because of the highly uncertain behavior of prices for this period. It is assumed that real labor and capital prices remain unchanged for the purposes of the discussion. If real labor or capital prices increase, there would be a positive impact on corn acreage as land is substituted for labor and/or capital.

Approximate impacts of time and real price increases on corn acreage are presented in Table 3. The time trend from equation (1) indicates a reduction of corn acreage of about 1.2 million acres per year from 1973 acreage levels, or an additional reduction of 3.6 million acres by 1976. The corresponding reduction implied by equation (2) is 1.8 million acres per year, or 5.4 million acres by 1976.

**Table 3. Changes in corn acreage harvested for grain implied by increases in selected variables (millions)**

| Increase in | Eq. 1 | Eq. 2 |
|---|---|---|
| Time by one year | −1.2 | −1.8 |
| Real price of corn by 10 percent | +1.2 | +3.0 |
| Real price of other crops by 10 percent | −3.3 | −6.2 |

The impacts of price changes from equation (1), which uses lagged crop year prices, are a gain of about 1.2 million acres from a 10 percent increase in the real corn price and a reduction of 3.3 million acres from a 10 percent increase in the other crop real price index. Thus, a 10 percent increase in real prices of both corn and other crops would mean a reduction of over 2 million acres of corn. In other words, to maintain corn acreage, the price of corn would have to rise by over 25 percent to offset a 10 percent rise in other crop prices.

The results from equation (2) indicate that a 10 percent increase in the weighted average (3-year) real price of corn would increase corn acreage harvested for grain by about 3 million acres, while a 10 percent increase in the weighted average price of other crops would decrease corn acreage by 6.2 million acres.

These results imply a continuing downward trend in corn acreage harvested for grain. The positive effects on corn acreage from an increase in the real price of corn and a shift to the longer-run adjustment equation (2) if production controls are removed is likely to be more than offset by an increase in the other crop price index proportional to the corn price increase. In addition the negative time trend is likely to continue at least through 1976, although an increase in real labor or capital prices would reduce the trend effect.

For example, if real corn and other crop prices increase by 10 percent from the prices used for prediction (3), i.e., from 37 to 41 and from 64 to 70, respectively (see Table 2 for prices and Table 1 for the prediction), and assuming these are weighted average prices, equation (2) predicts corn acreage harvested for grain of 67.4 million acres, as compared to 68.4 for prediction (3), if the time variable is 1973. Imposing the time trend to 1976, using these prices, predicted acreage is 61.8 million. If real labor price should increase from 43 to 45 by 1976, predicted acreage from equation (2) is 64.5 million.

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# INADEQUACY OF THE COST-BENEFIT RATIO AS A MEASURE OF THE PUBLIC INTEREST*

This paper questions the validity of the contributions of the cost-benefit concept to better government decisions in the resource area. Since government decisions, including those ensuing from pressures of private pecuniary interests (hereafter termed private) are not always in the best interest of the public, the distinction is made between what government *does* (hereinafter termed public purpose) and that often controversial area of what is *best* for the public (hereafter termed public interest).

Any formulation of what is best for the public must accord with accepted beliefs. Those holding a given set of beliefs have little difficulty with the conviction that their views identify with the public interest and that those holding conflicting beliefs are mistaken. Since beliefs change with changing economic and social conditions, what is taken to be the public interest must always be tentative.

Since the validity of the monetary ratio, as margin of profit, has been proven empirically in terms of private purpose, proponents of the cost-benefit approach apparently feel that the difference in the situations in which the private and public operate are not of such significance as to negate its use as cost-benefit ratio as a measure of the public interest. It is my contention that many of the differences between the private and the public are now of a nature which, in the resource area, cause the use of the cost-benefit procedure to be a highly questionable practice. Since I am unable to present empirical proof of its falsity, my comments are limited to indicating reasons for questioning its validity. In matters of science and practical affairs the burden of empirical proof rests with the proponents.

## Shadow Pricing

If prices more frequently served to guide the private in utilizing resources in the public interest or if prices were always the result of actions taken in the public interest or reflected consumer surplus or externalities or the basic needs of those without the purchasing power to satisfy them, one might not be so apt to question the validity of using the cost-benefit ratio. Many wants are created, solely for pecuniary purpose, and utilize resources which could better serve the public in providing other utilities. But where the withholding power of producers is limited, as in agriculture, technological development has frequently led to chronic overproduction, wasted resources, and low prices. On the other hand industries with the power to administer prices in their own interest withhold resources from the public. Price in the one case becomes a resultant, and in the other it serves as a target about which decisions center. In either case, externalities are seldom reflected in the price.

Cost-benefit practitioners suggest "shadow-pricing" —assigning prices where none exist and adjusting market prices to prices which would presumably prevail under competitive conditions—a "solution" which does not appear practicable as indicated by the editorial comments of a reviewer of an earlier draft of this paper: "Public welfare price quantifications are necessary to the use of cost-benefit as a public purpose calculus, but use of real world market prices, no matter how 'doctored' to transmute them into shadow prices that are valid 'public interest' quantification ('public welfare prices'), simply shifts the issue from the conceptualization and logic of cost-benefit to the question of empirical method for the transmutation. Simply to assert that in cost-benefit quantifications prices other than market prices should be used (as is frequently done by cost-benefit apologists) doesn't advance the ball very much—it simply begs the crucial issue—because any competent cost-benefit analyst or user has always known that but hasn't known how to do it. Doctoring market prices (how? analytical and logic structure? empirical techniques? all of which are unknown) falls back on the analysts' 'good judgment' which . . . might as well be left to the public decision-maker (legislature or executive) where it always has rested rather than go through the quasi-scientific (really the 'pseudo' or 'mythical' scientific) hocus-pocus of cost-benefit" [1].

## Use Values Lacking Monetary Values

Since society has an interest in all materials which man uses habitually and consciously to serve his purposes (hereinafter termed use values), the problem may not simply be the inability to handle and manipulate the monetary; the basic difficulty may rest with limiting the data for manipulation to the monetary. This is indicated by a reviewer of this paper as follows: Use values ". . . . that are scarce relative to the public interest are presumed in the conventional wisdom of economic policy analysis to have monetary or exchange value; they do so, however, only insofar as manageable *and* managed property rights attach to them. Insofar as such rights do not attach to them, they enter the economic process *as if* they are not scarce, in fact literally as *free* resources without monetary value

* The author is greatly indebted to Maurice Kelso whose comments on basic issues resulted in a near complete revision. I also wish to thank Ernest Grove, Malcolm Maclay, and Robert Lowerre for helpful suggestions. The author is solely responsible for the contents.

indistinguishable in this regard from those use values truly devoid of relative scarcity and hence devoid of monetary value even in the public interest" [1].

To warrant the assumption that the cost-benefit ratio appropriately measures the public interest, price must be demonstrated to be applicable to measure the utility to the public interest of use values for which no price exists, or that the failure to include such use values has no effect on the results. But to attempt in a cost-benefit ratio to include use values, relevant to the public interest but lacking monetary value, presents as nebulous a problem as that posed by shadow pricing.

Many use values with no exchange value, customarily taken for granted as part of "Nature's Bounty," are receiving increasing attention. Pollution, until recently of local significance, is now of more general concern as increasing numbers become aware of the overall dilemma. To some the threat is to the atmosphere, the land, and the water; to others, the threat is to profits and customary ways of doing things. Unfortunately there seems to be no simple way of comparing quantitative costs, affecting the profit margins so essential to providing goods and services, with the qualitatives of polluted resources. For both, the public interest has concern.

In sustaining life itself, one of the most significant services many of these gifts of nature render is to recycle man's effluent. This capacity, overall never before taxed, is now being challenged. The issue relates to many of the earth's resources but perhaps is most ominous to the use values held as common property. The threat of irreparable damage posed by pollution is disturbing. It is directed toward no one's private property but to everyone's common property—the joint property of the rich and poor alike, which when fouled for one is fouled for all. Unfortunately, in spite of our common sense belief and general acceptance of the monetary as the basis and measure of our judgments and of what is significant, it properly and justifiably assumes in our daily affairs no one can "buy out" from pollution.

In such matters, what people will put up with and the kind of world they wish to live in and leave behind them is strategic. A larger population may increase demand and profits and also increase pollution, crowding, and social tensions. For each of us these are matters of degree and kind which would appear impossible to measure exactly, nor would this appear necessary.

For mankind the qualitative measures the issues of overriding significance in terms of more or less, or yes or no. The monetary quantitative is as irrelevant to the issue of harmlessly polluted air when it cannot be bought because there is none to be had, as it is when it is everywhere available for the breathing. All use values are of public concern; only those that are scarce and withholdable from the market have monetary value; and those too seriously depleted by pollution have no value, neither use nor monetary. We face choices between degrees of environmental pollution. It is a trade-off between alternatives, and cost-benefit ratios provide little help.

Concern with the effect on resources of certain private and public activities has led to carrying these issues to the courts. The courts,[1] in ruling on disputes of this nature, tend to disregard the concept of value used in the cost-benefit ratio, apparently questioning its relevance as a measure of the public interest. Since the validity of a concept depends upon its applicability to the use to which it is put, the courts in failing to use the concept appear to indicate that they do not accept it for this purpose. They may be in effect saying that damage to certain resources could be so irreparable that it could neither be measured nor compensated for in monetary terms.

## Use Values Having Monetary Value

When use values become relatively scarce, the additional trait of monetary value accrues to them. This value is an addition facilitating acquisitive purpose, but under certain conditions it is suspect in terms of the public interest. David Ricardo placed this issue in perspective in a discussion with Lord Lauderdale concerning the value of water. Ricardo quoted Lauderdale as follows: "Let water become scarce and be exclusively possessed by an individual, and you will increase his riches, because water will then have value; and if wealth be the aggregate of individual riches, you will by the same means increase wealth" [5, pp. 261–2]. Ricardo argued that those who controlled the water could now charge higher prices, but others would be poorer since they would now give up a portion of their riches for water which they formerly had for nothing, and if water should be scarce there would not only ". . . be a different distribution of riches, but an actual loss of wealth." To the private, use value traits are secondary and significant only as they can contribute to acquisitive purpose; to the public they are significant in their own right, serving directly or indirectly to satisfy human wants. For the private they must be scarce to have monetary value; for the public, the more abundant they are the better.

Since the private measures the significance of use

[1] The following excerpts from two court opinions are typical of many recent decisions: in Reserve Mining Co. vs. Minnesota Pollution Control Agency involving the discharge of waste into Lake Superior, the court found ". . . even though there has been no substantial or convincing evidence of deterioration to date . . . the question of *potential* harm to the lake water then became the greatest concern of the Court . . ." [4]. The U. S. Corps of Engineers were enjoined by the court from continuing work on the Cross Florida Canal Project with the finding ". . . That unless a preliminary injunction should issue, the Plaintiffs would suffer irreparable damage for which there is no adequate remedy at law. . ." [2].

values in monetary terms, the cost-benefit advocates, in terms of marginal utility theory, faced no problem in constituting the dollar as the measure of the public interest. However, there is little existential proof to indicate that use value A that is high in price is of greater interest to the public because it is worth more to the private than use value B that is low in price.

Adam Smith indicated that certain use values have an import to the individual which may bear little relation to their civilization value [6, p. 28]. Precious jewels have little use value but constitute riches, which for the individual are measured in monetary terms. If all jewels were destroyed, those who owned them would suffer a loss in riches, but the loss of public wealth would be negligible. The cost-benefit concept fails to indicate whether a given monetary quantitative derives from use values of little public significance, but high in price by virtue of scarcity, or from use values of greater import to the public. The degree to which the monetary measure is the resultant of scarcity, and not of use values of public import, makes it suspect as a measure of the public interest. The fact that this is not indicated in the measure leaves something to be desired. The measure itself is a variable composed of two other variables (number of units of use values and price per unit), each of which is of separate concern to the public, and when they are combined as a monetary measure, the relative components of each are hidden.

Quantification for a specified purpose constitutes a valid exercise only when traits not included in the quantification can be ignored without affecting the end result. Maurice Kelso expresses this concern regarding the applicability of cost-benefit analysis to public land policy: ". . . It is easy under the all-too-human desire for definitiveness and certainty, for the bridge operators to be simplistic in their demands, confining that which they permit on the bridge to analyses comparable to those of private businessmen, eschewing the intangible, the non-marketable, the non-economic. In doing so, much that is worthwhile in public land management will be left behind" [3, p. 1683].

In quantifying use values in monetary terms for private pecuniary purpose, all qualitative differences important to the public interest can be ignored since only such factors as do not affect price will in that case be excluded from the monetary quantification. The margin of profit concept, dependent on the quantitative, adheres to the stipulation that numerical comparison can be indifferent only to those qualities which are irrelevant to its purpose. But there is reason to doubt that this stipulation is met when public interest qualitatives are quantified in monetary terms for inclusion in a cost-benefit ratio. If the public interest is in qualities as qualities, their exclusion from a quantification does not constitute valid procedure.

## Continuity and Change

Price changes play their significant role in the on-going course of events. Timely recognition of change is a primary requirement to which the private adjusts his priorities in order to maintain a margin of profit. Soil conserving practices, which under a given set of prices would not be profitable, at another time and under a different set, could be economically desirable.

In terms of marginal utility theory, the public interest equates with the private, and when expenditures for conserving practices are not in the private interest, neither would such action be in the public interest. But if prices increase by an amount that would make these practices profitable, such action would then presumably be in the public as well as the private interest.

While the public interest in many resources gradually changes with the needs of the public, as the arts are developed and new habits, beliefs, and customs evolve, the public interest can hardly be claimed to change in a manner comparable to prices. Each price change records a new private value. To accept the dollar as the measure of public value is to accept a fluctuating yardstick which yields a new public value with each change in price regardless of its cause or direction. The possibility that a priority, based on a cost-benefit ratio at a given point in time, may be reversed as prices change; this nullifies the means-end relation and places public policy on fragile ground

## Time Preference

Economic theory values the future in terms of a time preference derived from private futurity values. Interest rates affect the use the private makes of resources and, in cost-benefit ratios, are significant in establishing public priorities. But there are two time horizons, the one finite, relative to the private, and the other continuing, applicable to the public. Because of the difference, interest rates which are applicable for the private are hardly relevant to the growing recognition that many key resources are exhaustible. Yet current cost-benefit procedures discount the public interest in the future at rates that indicate the significance of physical resources to the finite interest of the private.

Enactment of the National Environmental Policy Act of 1969 establishes ". . . the continuing responsibility of the Federal Government to (1) fulfill the responsibilities of each generation as trustee of the environment for succeeding generations. . . ." Such actions by Congress indicate the belief that the public has a responsibility which the use of going interest rates in evaluating resources would tend to negate. In spite of the fact that man's actions are frequently shortsighted, such actions also appear to suggest that this is an issue that could better be left to an

informed electorate. The longer term problems which this and future generations, as links in a continuing civilization, face are primarily with physical resources, which have always been fundamental to man's welfare and which certain aspects of the monetary tend to confuse.

## Methodology

Proof of the basic hypothesis, that in the resource area the monetary constitutes a proper measure for evaluating public interest benefits and costs, is missing. In science and business, hypotheses are subject to empirical test whereas the cost-benefit concept is divorced from the end effects of its determinations. The margin of profit concept serves as a hypothesis which the private continually tests; the cost-benefit concept with its hypotheses exempt from proof and its responsibilities severed from the final outcome of its decisions is subject to no such discipline.

Public problems appear more difficult than those faced by physical science and the business world. But science has been perfecting its method for several centuries and business even longer. That public problems contain more variables and complexities due to the unique nature of their subject matter may be true, but many of these difficulties could disappear if applicable methods were available. Unfortunately, we have never tried to do very much about public problems. The ghost of *laissez-faire* continues to haunt the body politic, and the belief still lingers that many public problems, if only let alone, will go away.

If there is a lesson to be learned from the cost-benefit experiment, it is the need to adhere to the stipulation of physical science and business that conceptualizations employed in the solution of a problem must be grounded. If this is done, at least we will not spin our wheels in the comfortable conclusion we are doing something worthwhile. Although there are many things we accept on faith, methods affecting the public interest should not be one of them.

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# ON THE MISUSE OF SIGNIFICANCE TESTS

Statisticians are concerned about an over-emphasis on statistical significance tests in published research as evidenced by the large number of asterisks normally used to indicate statistical significance.

The most serious misuses of statistical significance tests arise due to misunderstanding of their implications—the probability of erroneous rejection refers only to any *one* statistical significance test. In most research, however, there exists a large number of statistical significance tests that one might perform. For example, in a 10 variable regression analysis, there is a choice of 10 tests for the individual regression coefficients alone. If all were performed, simple calculation of binomial probabilities reveals that there is a 40 percent probability that one or more coefficients will be found to be "significant" even if the analysis had been performed on a set of unrelated random numbers. In other words, such a procedure really only provides a 60 percent protection against rejecting a true null hypothesis. The point is that the interpretation of "significance" of several tests in the same model is not the same as it is for a single test.

This overstatement of the degree of protection becomes more marked and impossible to determine in the case of exploratory data analysis. In this type of study, a single data set is often subjected to several alternate models of estimation procedures, including, for example, the selection of variables in a regression analysis. Published results of such studies, however, usually include estimates and significance tests from only the "best" model or procedure. It is not difficult to demonstrate that, starting with a set of random numbers, it is possible by such methods ultimately to produce many "statistically significant" results.

A final point regarding this subject concerns the important distinction between practical and statistical significance. Statistical significance tests were initially proposed primarily for the analysis of small samples where results that would appear to be of practical significance could have arisen by chance. Thus, for example, the phenomenon of five heads in a row does not overwhelmingly prove that a coin is biased. Conversely, with extremely large samples, statistically significant regression coefficients can be obtained for relationships which have such a minor effect as to be practically negligible. Thus statistical significance tests should only be used to justify the advisability of interpreting those coefficients that appear to be of sufficient magnitude to be of importance.

All this is not to say that statistical significance tests should not be used. They are, if properly used, indicators of when a particular estimate does or does not represent a true phenomenon. Furthermore, the test statistics are themselves dimensionless numbers, and relative magnitudes of such statistics do give an indication of which estimates were more precise and of which variables may be more important to the predictive process.

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# Book Reviews

Forrester, J. W., *World Dynamics*, Cambridge, Wright-Allen Press, Inc., 1972, x + 142 pp. ($9.75)

Meadows, Donnella H., Dennis L. Meadows, Jorgen Randers, and William W. Behrens, III, *The Limits to Growth*, New York, Universe Books, 1972, 205 pp. ($2.75 paper)

Meadows, Dennis L., and Donella H. Meadows, eds., *Toward Global Equilibrium: Collected Papers*, Cambridge, Wright-Allen Press, Inc., 1973, x + 358 pp. ($18.00)

**Editor's Note: Because of the importance and controversial nature of the issues posed by these three books, it was decided to publish two sets of reviews representing disparate points of view. It should be noted that, as requested, George Brandow reviewed only the latter two books cited above. Day and Koenig voluntarily included the Forrester book in their assignment.**

The Club of Rome's "project on the predicament of mankind" is by now well-known. Jay W. Forrester, Professor of Management at M.I.T. and builder of computer models of what he calls "system dynamics," wrote *World Dynamics* (*WD*) to present a preliminary version of a model to show the consequences of population and economic growth. The two books reviewed here followed. *The Limits to Growth* (*LTG*) is a popularized version of *WD* and a somewhat more complete explanation of the data used. *Toward Global Equilibrium* (*TGE*) contains a first chapter by Forrester that summarizes *WD* and a book on urban growth; also included are papers by other authors on modeling specific pollution processes and on related topics. Much duplication exists among *WD, LTG,* and *TGE*.

Of the many broad issues raised by the books, three are important to this review. The first is concern about the effects of population and economic growth on sufficiency of resources, including the environment. This concern is accepted here as thoroughly warranted. The second issue is the state of knowledge about physical, economic, and social relationships, and about technological developments yet to appear, that will determine future outcomes. The situation seems to be that on some of these questions, present knowledge is fairly firm, on others it is woefully weak, and on still others it is nonexistent; some things such as the future of technology and social behavior under new kinds of stress simply are not knowable in advance. The third issue is whether the world model central to these books should be presented to the public as essentially true. The position here is, no: it is a perversion of science.

Essentially, the world model assumes that population and industrial output per capita grow exponentially unless checked. Resource requirements grow faster than either alone, as does pollution. Resources, including the environment, are limited, exhaustible. The denouement is tragic: if starvation does not drastically reduce the population, the lethal effects of pollution do. The complete model is somewhat, but not much, more complex than this.

The world is treated as a single system having one pool of resources, one economy, one culture. Simple functions describe the relationships among the few variables in the system. Numerical values for the functions are dredged up from fragmentary sources, usually with no theory to guide selection, and where data are lacking, they are simply manufactured. The effect of pollution on life expectancy, for example, is diagrammed as a line that extends horizontally well past the current level of pollution (itself a grossly defined concept) and then plunges toward zero.

Technology is not explicitly represented in the world model. Its possible future effects are examined by rerunning the model under assumptions that particular input-output ratios are reduced or resource availabilities increased. Given the built-in growth patterns of population and industrialization, technology so considered is unavailing in the end.

A number of important and interesting ideas are found in *LTG*, but none is original or dependent on the model. That it takes a long time for reduction of the birthrate to halt population growth is well known. So is the fact that the concentration of certain chemicals builds up in the food chain. One would have more confidence in the survey of such relationships if the writers were experts in the fields rather than searchers for numbers to plug into a model. In spite of their insistence, the conclusions reached by running the model are apparent from their assumptions.

The exercise is an abuse of a method that can be highly useful in appropriate circumstances. Its perpetrators acknowledge a number of weaknesses but brush them off as being immaterial to the results. Meadows *et al.* maintain that their highly aggregated

system is essentially correct and that more detailed data would only fill in information about subsystems —the macro structure is independent of the micro structure. Willingness to accept weak or fanciful evidence is coupled with a belief that what we now think we know will only be added to, not revised, by new knowledge gained in the future. Forrester argues, "The problem is not shortage of data but rather our inability to perceive the consequences of the information we already possess" [*TGE*, pp. 8–9]. Two decades ago, we possessed much information on the ability of DDT to kill insects harmful to man, but that did not enable us to perceive the consequences of using DDT. What is left out of a model may be as important as what goes in; though it is easy to point to important omitted relationships, no one knows all the ultimately essential knowledge left out of the world model.

The objection to the world model is not to the concern that motivated it nor even to its implications. The model simply does not represent the science-and-technology establishment being honest with the public. Rather, it uses the trappings of science—the computer, model-building jargon, charts extending to the year 2100—to sell a dubious product in a market receptive to tales of coming catastrophe.

To say that the books generate concern about a vital problem (the end justifies the means) is not an adequate defense for the Club of Rome, and one may doubt that this approach fosters the long-run social usefulness of science.

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On June 29, 1970, J. W. Forrester invited members of the Club of Rome to the Massachusetts Institute of Technology to determine if "the 'system dynamics' approach as already developed . . . was . . . a suitable methodology . . . to deal with the broad sweep of human affairs and the ways in which major elements of the world ecology interact with each other." For this purpose World 2 was developed "early in July" and used as a basis for ten days of discussion at the meeting convened on July 20. This model is described in *World Dynamics*. The *Stiftung Volkswagenwerk* then funded a follow-up model under the direction of Dennis L. Meadows. Called World 3, it is the subject of three books: *Limits to Growth, Towards Global Equilibrium,* and *The Dynamics of Growth in a Finite World,* the first two of which have already appeared.

The world models were "built specifically to investigate five major trends of global concern: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment . . . . With the models [the authors] are seeking to understand the causes of these trends, their interrelationships, and their implications as much as one hundred years in the future" (see D. H. Meadows, *et al.*, p. 21). The authors admit shortcomings but argue that, despite their preliminary state, the models are "sufficiently developed to be of some use to decision-makers." They make two specific claims. First, they claim to have produced "the only model in existence that is truly global in scope." Second, they claim to have identified two features of the long-term global situation important for policy: (1) given the current structure of the world system, economic growth on the planet will peak and turn down "in a rather sudden and uncontrollable decline" some time during the next century; (2) this decline and fall can be prevented by action that would yield zero population growth, zero net capital formation, increase the use-life and recycling of commodities, increase resource productivity, and reduce pollution emissions, but these steps must be taken soon. Meadows *et al.* believe their conclusions are so fundamental that revisions in the models will not alter them.

Critics have attacked the methodology, the assumptions, and the conclusions of Worlds 2 and 3. One has even gone so far as to say that the models are "worthless as science and as guides to public policy' [13]. We shall briefly evaluate all three aspects of the work. First, let us consider the methodology employed. It has given rise to considerable abuse and misunderstanding. Thus one encounters characterizations of Worlds 2 and 3 as ". . . significant retrogression[s] in scientific technique . . ." [8], "Rube Goldberg devices" [10, p. 1], and "contraptions" [8]. But a close examination reveals that they are equivalent to discrete approximations of simultaneous, nonlinear differential equations, five equations in World 2, 11 in World 3. The approximation (Euler's) is standard. It is also worth noting that conventional economic models can easily be expressed in the system dynamics lingo and simulated on the computer [3]. While *Newsweek* (13 March 1972) has referred to World 3 as "elaborate . . . a seemingly endless list of equations," Shubik [12] calls the models "extremely simplistic." Now five or 11 basic equations hardly comprise an endless list. Instead, the apparent complexity arises from the introduction of large numbers of auxiliary variables and the deKooning-like style of the DYNAMO flow charts. On the other hand, the number of variables and interactions included yield a model of development far less simplistic than the typical neoclassical growth or Keynesian macro model.

While the methodology is consistent and logically correct, it is not without actual and potential failings. We offer the following list of constructive criticisms, some of which involve only slight modifications in approach, others of which point out the need for parallel formulation in more conventional terms. (1) Introduce "variable step" simulation techniques to reduce possible truncation errors and lower computation cost. (2) Introduce optimal and adaptive

control techniques, including explicit economizing behavior. (3) Replace piece-wise linear functional relations with smooth nonlinear functions to reduce parameter numbers, simplify analysis, facilitate improved simulation techniques, and enhance the use of statistical estimation techniques. (4) State model relationships in "natural" multivariate functional form prior to decomposition to clarify model structure and empirical hypotheses. (5) Use statistical estimation techniques wherever possible to optimize the use of available data. (6) Express models in conventional mathematical notation to facilitate scientific communication, logical analysis, and statistical estimation. (This would not preclude enthusiasts from using the DYNAMO language).

We concur with the system dynamicists' advocacy of mathematical modeling and simulation. Yet we also believe one's enthusiasm for each should be tempered. It is possible that the mind accounts for far more factors than merely those of which it is consciously aware. Consequently, one should not be too quick to disregard the intuitions of somewhat fuzzy mental models. Simulation models, like those considered here, which leave out fundamental adaptive mechanisms in the real world may be misleading. Moreover, simulation may clearly *not* reveal all the "fundamental behavioral modes" of a given mathematical model; this is easy to show with examples even simpler than Worlds 2 and 3. As even simple nonlinear models may exhibit widely divergent "fundamental modes," plausible parameter values are extremely important. Hence statistical inference and estimation are not as unimportant as the authors prominently argue at several points.

Turning from general methodology to specific model content, what can be said about the realism of the assumptions embodied in the models? To answer this question, we undertook an evaluation of the individual components [4]. We found copious opportunity to improve the models and offer the following minimal suggestions (some of which have already been well stated by others). (1) Forrester and Meadows have neglected certain physical interrelations between their variables, the effects of which it may be desirable to investigate—for example, the dependence of agriculture upon nonrenewable resources or the linkage between agricultural production and pollution. (2) There are specific parameters and relations in Worlds 2 and 3 which are in need of modification. The table function linking investment to nonagricultural production in the Forrester model needs to be altered to prevent savings exceeding income. In the Meadows model the effects of changing the relationship between industrialization and desired birth rate should be investigated. Both models, it can be argued, are overly pessimistic in their assumptions about the size of the stock of virgin resources. (3) The possibility of factor substitution must be recognized. (4) The potential for automatic adjustment which exists within the framework of current governmental policies must be incorporated. Meadows and Forrester have substantially ignored important channels for such adaptation in their treatment of capital allocation, resource recycling, and continuous technological change. The tendency for desired birth rates to respond to economic conditions—and actual birth rates to respond to desired birth rates—should also be included. (5) More sophisticated and realistic control functions for pollution and population control, technology, and energy production should be explored. Many other more specific comments may be mentioned, though space limitations preclude them here [4, 2].

Thus, we find that the underlying hypotheses of the World models are indeed subject to considerable doubt, but if so, are the conclusions nonetheless believable? Many economists answer, no. At one extreme for example, Nordhaus and Tobin state that, "At present there is no reason to arrest economic growth" [9], and Solow argues that ". . . posterity will be richer than we are even if we make no special efforts in its behalf" [13]. Other scientists take the other extreme, Hubbert, for example, believes the following:

> It now appears that the rapid population and industrial growth that has prevailed during the past few centuries, instead of being the normal order of things and capable of continuance into the indefinite future, is actually one of the most abnormal phases of human history. It represents only a brief transitional episode between two very much longer periods, each characterized by rates of change, so slow as to be realized essentially as a period of nongrowth. [6, pp. 238–239]

Economists support their position with the argument that a properly modified market system will induce inventions, innovations, and investment in response to each new scarcity as it arises and soon enough to avert disaster [5, 7, 11]. We do not doubt the utility of markets, but to leave the fate of future generations entirely in the hands of today's market competitors seems to us a dangerous course if we wish to endow our heirs with initial conditions favorable to their pursuit of happiness and the continued development of our species. Indeed, it is in fact *absolutely false* to claim—and the claim is implicit if not explicit in much commentary on Worlds 2 and 3—that perfect markets must optimize an exchange between current and future generations! A neat counter example based on the dynamic utility function usually used by economists has been produced by C. W. Clark in an investigation of the economics of fishing. He concludes, "that if extinction [of a given species] is economically feasible, then not only will it tend to result from common-property exploitation, but may also result from the maximization of present value [even by a central planner], whenever a sufficiently high rate of discount is utilized" [1, pp. 10–11]. It seems to us, then, that engineering of the highest order, vigorous conservation policies and various government planning and control schemes

must be developed to augment existing market and institutional mechanisms.

One of the goals of Forrester and the Meadows team is to open up debate on the policies needed to prevent global disaster. They are possibly too eager to take credit here, for the debate was already intense when they came on the scene. Nonetheless, they did develop an alternative and novel dramatization of the awesome problem attending long run economic and demographic growth. And they have surely succeeded in intensifying the discussion in general and provoking economists in particular. If the debate now rises to a new level—if the publications reviewed here stimulate research into the dynamic interaction of variables too long considered separately, as it appears they will—then any irritation at their scientific shortcomings and hyperbolic style will hardly be worth further mention.

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**Boulding, Kenneth E., and Martin Pfaff, eds., *Redistribution to the Rich and the Poor: The Grants Economics of Income Distribution,* Belmont, Wadsworth Publishing Co., 1972, ix + 390 pp. ($4.95 paper)**

If the middle class is the silent majority, they have something to be silent about according to this excellent collection of papers, most published previously. The editors only slightly exaggerate when they say, ". . . the papers in this volume came pretty close to describing the 'state of the art' in two major fields—explicit public grants and implicit public grants" (p. 387).

Divide the economy into two components: the exchange economy where goods and services are traded on a two-way, *quid pro quo* basis and the grants economy where transactions are one-way "gifts." The dominant exchange economy, known to be inherently unequal in providing rewards according to one's resources rather than one's existence, is justified in an equitable society by the grants economy which presumably provides for those unable to participate effectively in the exchange economy. The editors state that, "other things equal, we would, for example, presume that the grants would help ameliorate the inequality in income distribution wrought by market forces; that is, we would expect the pattern of redistribution brought about by the grants economy to be highly progressive in order to compensate for the regressive pattern of market distribution of income. That we reject this hypothesis on the basis of empirical evidence presented in this volume is evident at almost every turn" (p. 4). Author after author relentlessly documents the regressive distribution of grants.

Medicaid was designed to eliminate the inequality resulting from the matching requirement of federal funds released to states. The result? Bruce Stuart asserts that four rich states—New York, California, Massachusetts, and Michigan—received nearly two-thirds of all Medicaid benefits despite the fact that together they contain less than one-quarter of the nation's poverty households in 1967–68. In addition each of these states contributed considerably less than they received in benefits (p. 159). States that received the least benefits were primarily low-income agricultural states in the South and West. The author concludes that, "if we consider equity a primary goal of public assistance, then we can purchase improvement only at the price of 100 percent federal financing of *all* welfare programs" (p. 168).

Martin Pfaff and Anita Pfaff, after examining the implicit grants of the personal income tax, summarize that "under present law implicit public grants provide a redistribution to the wealthy"; they then state that ". . . it seems somewhat bewildering that more that one-half of the nominal tax yield is devoted to redistribution to the wealthy" (pp. 201, 202).

That grants go to the less needy within the groups eligible for benefits is reaffirmed by Henry Aaron: "Tax benefits on housing provide largest benefits to recipients of larger than average income whose experience with wealth is typically not limited to their own houses. They [tax benefits for housing] provide negligible aid to lower-income households, most of whom have not experienced the salutary discipline of property management" (p. 218).

The classic analysis by W. Lee Hansen and Burton Weisbrod in Chapter 4 demonstrates that public higher education in California redistributes wealth toward the rich, a finding also reported for other states in studies not found in this volume. However, this volume does not report the finding for several states that public elementary and secondary education redistributes wealth from higher to lower income families (see David Holland, *Southern Journal of Agricultural Economics* 5:71–79, July 1973).

Inflation has been called the "cruelest tax of all," but for whom? Not for the poor, according to Robinson Hollister and John Palmer, who in their outstanding Chapter 14 assert: "Contrary to popular belief, only a small percentage of the aged poor (about 10 percent) received money from pensions, annuities, and other forms of fixed valued income" (p. 251). Of course many of the poor are living on a "fixed income" from public transfer payments, but the authors show "there have been surprisingly few cases in which even for a given year rises in public transfer payments have lagged behind rises in the price level" (p. 262). The poor benefit more from the higher employment than they are hurt by the inflation associated with it. The authors estimate that a drop of 1 percent in the unemployment rate would remove about a million to a million and a half persons from poverty who would not have been removed otherwise. The authors conclude that ". . . the poor as a whole must be gaining both absolutely and relatively in economic well-being during periods in which inflationary processes operate" (p. 270).

Chapter 6 by Charles Schultze on the distribution of farm subsidies is of special interest to agricultural economists. The chapter draws heavily on research of the U.S. Department of Agriculture, James Bonnen, and others. As expected, the author finds program benefits concentrated among higher income farmers. He recognizes benefits of price stability from commodity programs to farmers, but fails to recognize that such stability also benefits consumers.

This volume bridges the hiatus between the vast literature of neoclassical economic theory which emphasizes efficiency, and radical economics which emphasizes conspiracy, turning to theories of Marx and secondary labor markets for inspiration to overhaul if not overturn the system. The implicit assumption of this and like volumes is that the "perverse" distributional impacts found for public policies will arouse public indignation and result in more equitable programs. This presumption may be erroneous. Could it be that the political process is working very well indeed and these "perverse" distributions are exactly what is intended and will continue even in an informed society? The volume largely ignores the incidence of taxes. Together, the overall system of taxes and grants redistributes income from the rich to the poor.

Many economists will find disappointing the lack of analytical elegance in this volume. Analysis of distributional effects does not lend itself to the rigors of neoclassical theory applied to problems of efficiency. Yet the analysis of distributional impacts poses challenging methodological problems and is no place for economists who, like Charlie Brown, are "best at things that are pretty much a matter of opinion." Equity issues deserve our best efforts.

The gap between current income from all sources in the poverty threshold of the poor has remained at approximately $10 billion for several years and has stubbornly withstood the onslaught of enough money thrown at it to remove the gap several times over. Although this volume does not detail the location of the gap, I hypothesize that it exists disproportionately among the rural poor. This as well as better estimates of trade-offs between equity and efficiency need study.

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**Frankel, Francine R., *India's Green Revolution: Economic Gains and Political Costs*, Princeton, Princeton University Press, 1971, vii + 232 pp. ($7.50)**

This book is a convenient introduction to the impact of the Green Revolution in India and to its consequent social and political outcomes. The author describes the techniques being introduced, the problems of adapting them to the climate and irrigation facilities of each region discussed, and the degree of success achieved in their implementation. The extent of technique adoption is explored, as is the impact of this adoption on agricultural laborers, tenants, and large and small owner-cultivators, with much attention being given to the resulting political unrest and the development of new strategies among various political parties in response to these changing conditions.

The study was conducted in one district in each of the following Indian states: Punjab in the northwest, West Bengal in the northeast, and Andhra Pradesh, Tamil Nadu, and Kerala in the south. Punjab is a wheat growing state, while rice is the major crop in the other four. The high-yielding wheat varieties in the Punjab district have had phenomenal success starting with 170 acres in 1965–66, increasing to 5 percent of the wheat acreage in the following year, and covering 90 percent of the land in wheat in 1968–69; a doubling of yields and increases of net income of about 70 percent per acre provided the incentive for rapid spread of the new varieties. By contrast in the rice areas, the results have been much more modest.

Professor Frankel collected the data in 1969 by interviewing state and district officers as well as farmers and farm workers in six to nine villages in each district. The bulk of the book is based on the estimates and opinions gathered from those informants. The only quantitative data presented are offi-

cial statistics on yields and production and on the distribution of farms by size.

The author gives an excellent account of the difficulties in introducing new rice varieties, with problems arising because the varieties were not well adapted to rainfall and temperature patterns as well as seasonal availabilities of water in irrigation canals. These problems caused a premium to be placed on ownership of an irrigation well; such ownership decreased dependence on the vagaries of monsoon rains and on the uncertainties of water supplies in irrigation canals, thereby enabling cultivators to plant a crop at the time required to obtain a high yield and harvest early enough to allow the planting of a second crop.

The crucial importance of irrigation wells means that the benefits of the Green Revolution have been most readily available to cultivators whose farms are large enough to justify investment in a well. Smaller owner-cultivators, tenants, and laborers have benefited less or not at all. The author concludes that smaller owner-cultivators have either incurred high fixed costs and indebtedness by installing a well (the tendency in the Punjab) or have not been able to obtain a dependable supply of irrigation water (the tendency in other states).

With respect to tenants and laborers, the issue is whether these groups will participate in increased agricultural incomes generated by the Green Revolution. Sharpest conflicts have arisen between laborers and the larger owner-cultivators, particularly over harvest wages which have traditionally been paid with a share of the crop. Landowners have resisted worker demands by importing harvest labor from poorer districts, the workers have used strikes, and both sides have resorted to political pressure and violence. The author reports an increasing interest of the landowners in mechanizing the harvest so as to diminish reliance on laborers.

Of particular interest is the manner in which the author analyzes the relation of uneven distribution of the benefits of the Green Revolution to political strategies and political conflict (the author is a political scientist and presumably most interested and qualified in this area). The author interprets the political conflict as (1) a shift from factional (clientele-based) politics to politics based on divergent class interests created by the Green Revolution; (2) an exploitation in particular by the Communist Party of India (Marxist), abbreviated as CPI(M), which seceded from the parent Communist Party of India in 1964 and was committed to a more militant strategy of peasant organization and strikes and not just to parliamentary politics; and (3) the CPI(M) finding greatest opportunity for action as a member of anti-Congress party coalitions in several state governments. The author also believes that the same conditions contributed to Mrs. Gandhi's landslide in national parliamentary elections in 1971, with the increasing cleavages in rural society making for the success of Mrs. Gandhi's strategy of direct appeal to the rural voters over the heads of local leaders and clientele-based approaches to getting out the vote.

This book is extremely valuable in illustrating the many ways in which needed technological progress brings with it inequalities and severe social stress even when the introduced technology can be widely utilized within the existing social system. The Green Revolution—yield-increasing, based on divisible inputs like seed and fertilizer, not requiring the use of labor-saving machinery, and available to all farmers large and small, if only access to irrigation water were made widely accessible—seemed tailor-made to the needs of less developed countries for increased production and for wide participation in development by most rural families.

The inequalities the author describes are real and important. But I am somewhat more wary of the conjectures and conclusions that Professor Frankel draws from her data. It seems to me that her economic gains-political costs model is oversimplified and possibly misleading. This model seems to assert that India first attempted a community development and land reform policy approach designed to provide incentives for labor-intensive production by small farmers; this might have achieved both economic and political gains but was defeated by powerful land-owning interests (p. 4). Subsequently the policy approach was shifted to achieving production increases by the application of science and technology (pp. 5–8); however, this is a viable model in terms of economic gains and minimal political costs only in the exceptional case of the Punjab and the adjoining state of Haryana, where acreage size of farm is larger and distribution of land ownership more equal (p. 200). In the rest of India smaller farms and higher proportions of tenants and laborers either limit economic gains and/or increase political costs (pp. 200–1). Thus Indian policy has come full circle back to the issues of sharing benefits of technology (p. 10).

I question several aspects of the model's assertions. If the new rice varieties were better adapted to Indian rice-growing regions, would small size of farm have been as much of an obstacle as the author suggests? Do the political costs cited owe their origin to the Green Revolution? Communist party strength in three of the states described (Andhra Pradesh, Kerala, and West Bengal) long antedates the Green Revolution. Finally, are there alternatives to basing development on technological change? I think that agrarian reforms and community development projects are not alternative means for securing needed increases in agricultural production, but are the means for attempting to achieve greater distribution of the benefits of development and to prevent premature displacement of labor under conditions where technological change is occurring.

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**Fuchs, Victor R., ed., *Essays in the Economics of Health and Medical Care*, New York, National Bureau of Economic Research, 1972, xxii + 239 pp. ($8.00)**

**Grossman, Michael, *The Demand for Health: A Theoretical and Empirical Investigation*, New York, National Bureau of Economic Research, 1972, xvii + 115 pp. ($3.50 paper)**

These two books are the first NBER volumes reporting on work in health economics. The first is a collection of essays by Victor Fuchs and his colleagues at the National Bureau of Economic Research; it is perhaps best described as two collections of essays which happened to be bound together into one book. The first four essays, all by Professor Fuchs, deal with a range of major issues in a non-technical fashion. The remaining five essays, which comprise about three-fourths of the book, are all empirical analyses of more narrowly defined subjects.

The unifying theme of the first four essays concerns the problems of the American health care system. Of course, the principal problem is performance or "value for money." Simple arithmetic shows that enormous quantities of resources are poured into the system. But what output is obtained for this expenditure of resources?

This question is discussed in the first essay in the book. Fuchs identifies three types of outputs; improvement in health, validation services, and other consumer services. As he notes, our suspicions about the system's performance relate to its ability to produce the first type of output. Although resource inputs have grown rapidly over the past several decades, mortality rates and other indicators of health status have been relatively stable. Similarly, other countries seem to be achieving higher levels of health output with smaller quantities of inputs. The conclusion that our health care system is relatively inefficient seems inescapable. While Fuchs accepts this conclusion, he does not accept it uncritically. For example, he points out that some portion of rising health expenditures may simply reflect a shift in the provision of services (such as "hotel" services) from nonmarket to market production, rather than an increase in resource inputs. He also argues that high and non-declining mortality rates may reflect the deleterious effects of the life styles of an affluent society.

What features of the system explain this poor performance? To this question, which is considered in some detail in essays two through four, Fuchs provides fairly conventional answers. In fairness, however, we should acknowledge that these essays read like conventional wisdom because they are part of the literature from which this wisdom was distilled. In several places, the quality of Fuchs' exposition serves to clarify and extend our understanding. Most noteworthy is his discussion of the "technological imperative" in medicine in essay four. His emphasis on the potential conflict between societal objectives and the physician's concern for the best technologically possible treatment for his patient is even more appropriate today than it was in 1968 (when this essay was written).

What of the solutions to these problems? In keeping with the cautious and critical tone of these essays, no specific solutions are offered. It is suggested that a more rational organization of the health sector is required and that physicians must play a role in designing this new organization. But rather than trying to sketch what this will or should look like, Fuchs prefers to stress the complexity of the task. Such moderation is in marked contrast to much health care literature and, I think, contributes to the value of these essays as educational material. Whether it is a virtue from a political viewpoint as well is for the reader to judge.

Of the five remaining essays, two are empirical studies of the demand for medical care. Although K. K. Ro's study of variations in hospital use begins with some interesting observations about the complexities of the notion of demand when physicians as well as patients participate in the purchasing decisions, the reader soon is mired in a swamp of detailed comments about the coefficients of the dozens of independent variables included in the analysis. Since no detailed theoretical framework is used to organize and interpret these findings, the result is at least moderate confusion. Morris Silver's analysis of variations in medical expenses and work-loss rates is centered around two issues: the income elasticity of demand for care and the extent to which time lost from work is determined purely by health status rather than by consumer choice. He obtains unusually high estimates of the income elasticity of demand, and it seems very likely that his estimates are biased upwards by covariation between income and omitted variables, in particular, prices and insurance coverage. In his work-loss days regressions, Silver interprets intermittently significant coefficients for income level and the wage rate to imply that work-loss days is not a "pure" health status measure. This interpretation might be questioned on the grounds that income levels effect health status directly (as Fuchs suggests) and that the negative wage rate coefficients are biased downward because of simultaneity. Furthermore, Silver's assumed dichotomy between "pure" health status measures and choice variables vanishes in a demand-for-health model (such as Grossman's).

The seventh essay is a brief note, by Fuchs, Rand, and Garrett, on the distribution of earnings in health as compared to other industries. The eighth and ninth essays are econometric analyses of interstate and inter-SMSA variations in mortality rates. In the first of these, Auster, Leveson, and Sarachek attempt to measure the health-improvement output of medical services, that is, their negative impact on age-adjusted mortality rates. Their principal findings are that the elasticity of mortality rates with respect to

medical services is indeed negative but only about one-half the size of the (negative) education and (positive) income elasticities. Their positive income elasticity supports Fuchs' conjectures (noted above) about the deleterious effects of affluence on health.

Morris Silver's principal concerns, in the ninth essay, are to investigate further the positive income effect on mortality and to examine differences between races and sexes as to the importance of various mortality determinants. His results generally support the positive income-effect hypothesis except when education is excluded from his regressions.

These last two essays are interesting explorations in a relatively underdeveloped area of research. However, the use of different methods might be more fruitful here. Where our concern is with the improved health outputs of specific policy measures, more narrowly defined dependent and independent variables would be desirable. On the other hand, in estimating the full range of such effects as income, education, and urbanization on health, one wonders whether the single-equation approach used in these studies is optimal. In both analyses problems of collinearity are very substantial, and coefficient estimates are rather unstable. Estimation of structural equations in a larger model might reduce these problems somewhat.

It is difficult to offer recommendations about the use of this book since its two parts speak to very different audiences. The four essays by Fuchs are widely accessible discussions of some very basic issues. The five remaining essays are variable in quality and will appeal primarily to scholars working in this area. For others who merely wish to sample the technical literature on health economics, these essays may not be the best choices available in the literature.

In contrast, Michael Grossman's *The Demand for Health* is clearly valuable reading even for those with just a passing interest in health economics. In Grossman's theoretical model, which is a major innovation, he treats the demand for health (and the derived demand for medical care) as determined in the context of a life-cycle model of human capital investment. Of course, if in reality consumer behavior in demanding health is short-sighted, characterized by substantial ignorance, and influenced by physician preferences, this model may yield unreliable predictions.

Three types of empirical results are presented by Grossman—estimates of the demand function for health, estimates of the production function for health, and estimates of the demand function for medical care. In most of his demand-for-health equations Grossman finds that education and wage rates are positively related to health while income and age have negative impacts. Coefficient estimates are generally significant and consistent with theoretical predictions, although the results based on survey data appear to fluctuate when different sub-samples are analyzed. Results from two-stage estimation of a health production function (which excludes the wage rate but includes medical expenditures) are generally consistent with these findings and indicate a small positive impact of medical care on health. Coefficient estimates for education and the wage rate are, however, insignificant in the demand for medical care equations, although Grossman argues that this is due to biases resulting from measurement error.

All in all, Grossman's results are fairly consistent with his model's predictions. This is somewhat surprising given that his empirical work takes no account of price variations, insurance coverage, availability of services, and other variables which have been found to influence the demand for medical care in previous studies. Because of these omissions, his results are not wholly convincing. But they do establish that his model of consumer behavior merits further consideration and testing. At a minimum, Grossman has enhanced our ability to understand and interpret evidence from future empirical studies.

David Salkever
*The Johns Hopkins University*

**Knapp, Joseph G., *The Advance of American Cooperative Enterprise: 1920–1945*, Danville, The Interstate Printers & Publishers, Inc., 1973, xvii + 646 pp. ($9.95)**

This is the second in a series of three books by Joe Knapp covering the history of cooperative development. The first book, entitled *The Rise of American Cooperative Enterprises,* covered the period 1620 to 1920. This book covers the period 1920 to 1945. To me, this is a most interesting period in the history of cooperative development.

The highlight of the book is in the first eight chapters. Here the development and demise of Sapiro's effort to gain bargaining power for producers is detailed. The conditions leading up to the passage of the Capper-Volstead Act are explored. Considerable detail is provided on the issues surrounding the McNary-Haugen Bill and the eventual establishment and demise of the Federal Farm Board. This section of the book represents a substantial contribution to the literature by providing a perspective of cooperative development and of the interplay between cooperative activity and early stages of farm program and policy development for U. S. agriculture.

From the ninth chapter on, the narrative proceeds through the chronological development of purchasing cooperatives, consumer cooperatives, credit and insurance cooperatives, relief cooperatives, TVA, and rural electric cooperatives. Farm program developments in the 1930's are also reviewed. The main contribution of this section from my perspective is

in terms of the reach and impact of the cooperative movement and the rapidity of the movement in a period beset by surplus agricultural products, low farm prices, and economic depression.

While a blow-by-blow chronological organization may have considerable historical value, much impact is lost in this discussion. The discussions of the cooperative policy as it relates to farm programs would have been more effective had it been pulled together in one section. Instead it is separated by unrelated topics such as purchasing and consumer cooperatives. The effect is repetitive with the author covering much of the same ground over and over without making much headway.

The greatest value from history is in the implications for the future. The book quickly and clearly provides a reminder that few problems or ideas are truly new. In fact, many of the problems and issues which confront cooperatives today have also been encountered before. The Sapiro commodity marketing movement is illustrative. One question is whether conditions have changed sufficiently in agriculture, the general economy, and in the cooperative sector to make the current bargaining movement any different from the rather dismal and disconcerting effort that the Sapiro movement was. Another case in point involves the role cooperatives might play in current grain stocks policy issues *vis-à-vis* the experience with the Federal Farm Board in the 1930's. Unfortunately, Dr. Knapp does not tackle such questions. This seriously limits the value of the book as an inferential base for decision making in the present and future.

The author does a good job of focusing on people —leaders in government and industry. He strengthens this approach by developing their attitudes with respect to various approaches to problems. He then develops what action was taken. In concentrating on people, the contribution of eminent agricultural economists such as O. B. Jesness, John D. Black, Edwin G. Nourse, and John K. Galbraith to the cooperative movement becomes very apparent. There are some important omissions from the book. For example, the Agricultural Marketing Agreement Act of 1937 is hardly mentioned. Yet it is a key piece of legislation which has provided direct benefit and support for cooperative activity. The general development and problems encountered by marketing cooperatives is quite weak. It seems as though the author did not cover in detail these areas with which he was most familiar.

Who should read this book? The book has primary value as reference material. It should be particularly valuable to many of the students of the present generation entering the cooperative movement who must rely on historical accounts rather than experience to learn from the past.

Ronald D. Knutson
*Farmer Cooperative Service*

**McKinnon, Ronald I., *Money and Capital in Economic Development*, Washington, D. C., The Brookings Institution, 1973, xii + 184 pp. ($7.50)**

In this book Professor McKinnon stresses the importance of establishing efficient capital markets and of the liberalization of international trade as a strategy for promoting economic development. He hypothesizes that fragmentation of the capital market ". . . causes the misuse of labor and land, suppresses entrepreneurial development, and condemns important sectors of the economy to inferior technologies" (p. 8). He develops the theoretical arguments in support of his thesis and contrasts the favorable experiences of such countries as Korea, Indonesia, Taiwan, Japan, and Western Germany with those of Argentina, Brazil, and Chile.

The sections advancing the theoretical arguments which establish the importance of the real return of holding money for the development process in countries with imperfect capital markets are excellent. In McKinnon's view, ". . . monetary mismanagement resulting in high inflation may be much more damaging than prevailing theory would suggest" (p. 67).

It is unlikely that this book will resolve some of the long standing arguments which are associated with the structuralists concerning the causes and functions of inflation in the less developed countries. The limited number and the special circumstances of the success stories cited in this book are weaknesses. More empirical work is required; the book's emphasis is on the theoretical arguments. But this is a very useful book, and it is hoped that it will spawn individual country research where more attention can be directed toward other institutional features of the economy.

Donald A. Wells
*University of Arizona*

**Nader, Ralph, and Mark J. Green, eds., *Corporate Power in America*, New York, Grossman Publishers, 1973, x + 309 pp. ($7.95)**

*Corporate Power in America* records a 1971 Washington Conference on Corporate Accountability. Economists, political scientists, and lawyers were to "discuss proposals to restrain corporate power . . . and . . . to push beyond diagnosis to prescription . . ." (p. vii). It typifies conference proceedings. Speakers with a wider range of opinions would have improved editorial (and professional) content. It has duplication and a fairly unchallenged viewpoint. Authors pile on gloom about corporate power, and they often mire in rhetoric. The interdisciplinary nature and unabashed zeal of the book commend it.

The book includes useful treatments of history on specialized areas, interesting case examples, interdisciplinary slants on some social issues, and ex-

uberant and enjoyable language. The authors come in and out of focus on a central paradox, best stated as the conflicting wisdom of a weak corporate structure vs. that of a powerful one. Should we control, or should we emancipate the market (the corporation)? Should we keep a singular, identifiable, controllable constituency, or should we pluralize it? Should we trust the corporation with responsibility for solving our social ills, or should we keep the fox out of the chicken coop? Should we make the private corporation complementary to public institutions, or should we hold public and private institutions separate? Should we allow some "soul" in the corporation or should it be secular legally, operationally, and with regard to its purpose? The diverse views of this compatible group suggest that answers are not obvious. The book serves in crystalizing the arguments, if not in meeting its avowed aim of mobilizing a force to prescribe remedies.

Chapter I, "On the Economic Image of Corporate Enterprise," was reserved for Professor Galbraith. He outlined two views of corporate enterprise. First, the private (or traditional) view is that it "can be private because its operations are subject to the regulation . . . of the market. The market allows of private purpose because it keeps it aligned with public purpose" (p. 4). Second, public view "portends a public development, foreseeing that the great corporations eventually become public enterprises. It invites the use of a word long banned from reputable discussion in the United States . . . socialism" (p. 9). He makes two points—the first is of substance; the second is redundant. First, private view and public view are polar positions, and "there is no natural obligation to be neutral between truth and error." Second, Professor Galbraith prefers the public view.

"Governing the Giant Corporation" by political scientist Dahl, proposes a Senate investigation of "politics of business." He assumes that "the large corporation should be considered as both a *political* system and a *social* enterprise" (p. 11). His detailed series of studies is impressive and is acknowledged by others.

"The Politics of Corporate Power" is opened by Senator Fred R. Harris quoting from *Fortune* about Nader, "Behind all those good works in the name of consumerism . . . his real target is corporate power" (p. 25). This distinction is not that clear to all authors, but the Senator concludes that the "problem is corporate power." Moreover "this power is not only economic . . . It is also political" (p. 25). He outlines with interesting case histories four areas of political power misuse. His discussion was more provocative before recent events, but is still illuminating on campaign spending violations, use of advertising to translate economic power into political power, tax and special advantages on public issue time, direct lobbying, and political power abuses in job exchange between industry and government. For some the two pages on Earl Butz will be fun. The Senator makes a plea that we "politicize corporate issues." He concludes, "We must insist that every man and woman who runs for President, Senate, or Congress face up to the questions of corporate power in our country . . ." (p. 41).

"The Corporation and the Community" by Mark Green is a plea for economists to explain "the paradox of a malfunctioning economy with a trillion dollar-plus GNP . . . to the average American (who) often has great difficulty comprehending the economics of his immediate environment" (p. 42). This chapter reads like most reports of Mr. Green's "Accountability Research Group." He ties various studies (often old), his own hypotheses about social evils, and some corporate abuse examples to unfortunate community happenings. The interesting result is to be read with care.

"The Case for Federal Chartering" by Ralph Nader effectively treats federal chartering. The historical material is useful. He makes a strong case for federal over state chartering since corporations stoop to the lowest common denominator, or weakest state incorporation law. He wants an FCA—Federal Chartering Agency—and Corporate Bill of Obligations with provisions for: corporate democracy, strict antitrust standards, increased corporate disclosure, constitutionalization of corporation, and rules for consumer protection.

"Corporate Democracy: Nice Work if You Can Get It" by law professor Flynn is a general discussion of corporate control. He treats the property rights background justification of the current legal constituency of the corporation—the shareholder—but says the shareholder "has not and cannot exercise the franchise in large corporations because of the wide dispersal of stock and the inherent power of management" (p. 105). Other possible constituencies include "the general public, the consumer of the particular corporation's product, the government, and employees . . ." (p. 105). He concludes "the only cohesive, workable, and effective constituency within view is the corporation's work force" (p. 106).

"Corporate Secrecy vs. Corporate Disclosure" is by our own Willard F. Mueller. It adds specificity about disclosure but is often duplicated elsewhere. Mueller's text is "Contrary to the assertions of many corporate spokesmen, corporate secrecy—not corporate disclosure—is the great enemy of a market economy in a free society" (p. 111). He dramatizes the urgency of the case and argues for more disclosure, especially by larger firms and conglomerates. He is more pessimistic than others as to the SEC's being our one faint hope for adequate disclosure. He places his hope in federal chartering.

"The Antitrust Alternative" by economist Adams reviews national economic policy and abhors Mr. Nixon's current game plan which if it ". . . is intended to replace competition as a protective mechanism for the public interest, I wish to register my

dissent and predict its failure . . . the independent regulatory commissions . . . have proved to be near-disaster" (p. 133). He endorses the federal charter as the antitrust vehicle to monitor competition.

"Corporate Social Responsibility: Shell Game for the Seventies?" by lawyer Henning explains that "corporate social responsibility" is focused on the subcorporation since, "The resources for solving our urgent problems are largely controlled by them" (p. 151). He calls such responsibility a myth and pleads for corporate democracy while acknowledging that it "does not guarantee corporate social responsibility" (p. 168). He then writes off hope for public social responsibility and ends up in despair.

"Citizen Counteraction?" by political scientist Hacker contrasts the strong social responsibility placed on corporations in Europe with freedom here. The fact that sales of the 500 largest corporations doubled 1954–1969, while total tax revenues expanded less than 60 percent, suggests to him unwise preoccupation with "big government" as contrasted to "big business" (p. 173). Although fever of citizen concern is not high enough to precipitate citizen counteraction either by corporation pressure or by paying the bill publicly, he wants the issue kept hot and thinks it will come to a head "when the United States has its next serious depression" (p. 181).

"Deterring Corporate Crime" by social ecologist Geis languishes in comparing street crimes with suite (white-collar) crimes. The chapter is somewhat interesting, but needs more interdisciplinary tailoring.

"Courts and Corporate Accountability" by law professor Miller argues in depth synonymy of corporate accountability and corporate responsibility. He traces an interesting history of our court system and builds some hope for the courts, only to drop us with, "law reflects the power interests of the community. It will be changed—accountability will be effected upon corporations—at such time as there are new configurations of power, in the political sense, operating throughout the nation. The name of the game is still 'politics' not 'law'. . . . The fate of the judiciary in the modern state seems to be a diminution in importance" (p. 213–214).

"Halfway Up from Liberalism: Regulation and Corporate Power" by attorney Lazarus rejects the assumption that the New Deal "was the yardstick by which liberals should judge their works today" (p. 215). He discusses regulation reforms: (a) "tinkering" reforms for improving the existing system; (b) "creating new agencies" where he is pessimistic about effectiveness of an independent consumer protection agency as well as federal incorporation; and (c) "deregulation" for "liberation" of certain industries from regulatory controls, especially "naturally competitive" industries including agriculture. He holds that "the most original contribution of the new consumer movement for reforming regulation is the concept of consumer, or public interest, advocacy" since "the integrity of regulation cannot be guaranteed from within the government . . ." (p. 229). He concludes, disdainly, "Regulation of industry is one of the least successful enterprises ever undertaken by American democracy—a conclusion flatly contradicting the conventional liberal wisdom of only a decade ago" (p. 231). ". . . my main hope for reform lies with the establishment of a counterweight of public interest lawyers. This hope itself is not obviously a practical one . . ." (p. 233).

"Public Enterprise" by economist Shepherd compares U. S. public enterprise with that in Europe. He holds that "public enterprises are already extraordinarily pervasive in this country" (p. 235) and provides an interesting and useful cross-classification of public enterprises by degree of control and subsidy (p. 237). He sets some priorities on appropriate types of public enterprise and makes a case that we should at least experiment with certain of these. He concludes, "All in all, public enterprise has not had a glorious track record, here or abroad" (p. 254). The poor track record of the private sector, however, suggests to him some judicious experimentation.

Robert Townsend, former chairman of Avis Rent-A-Car, treats "A Modest Proposal: The Public Director." He proposes a public director in manufacturing companies with $1 billion dollars of assets. The annual budget would be $1 million of company money with his salary in the $50,000 range and the rest for scientists, engineers, lawyers, and accountants, some permanent and some not, to be on call to develop answers to questions which they feel the company should be asking. Strong justifications for his proposal are its catalytic effect on board meetings and its pressure on top management.

CHARLES E. FRENCH
*Purdue University*

**Zarembka, Paul, *Toward A Theory of Economic Development*, San Francisco: Holden-Day, Inc., 1972, xiv + 249 pp. ($11.95)**

The agriculture-industry transformation theme has been avidly pursued in the dual economy literature at different degrees of mathematical abstraction and at different points of the spectrum from partial to general equilibrium analysis. Zarembka offers a consistent and most parsimonious general equilibrium model of the dual economy. There lie both the strength and the weakness of the book. The basic conclusions flow effortlessly from the solution of the model and are formulated into simple and powerful propositions. Parsimony, however, is built on strong assumptions that often compromise both the realism and the relevance of the analysis.

The basic specification of the model consists of the agricultural and the industrial production functions. The former has labor as an independent vari-

able, with land, water, and farm practices subsumed under the constant term that represents an exponential rate of technological change. The industrial production function has as arguments technological change, labor, and capital. In this system the linkage equations are the derived labor demand and each sector's demand for the other sector's output. Given the labor supply and each sector's output supply, the equilibrium prices, and quantities of labor, agricultural output and inudstrial output are endogenously determined. Zarembka, however, does not go that far. Careful spelling out of the mechanism of the labor and output markets has been sacrificed on the altar of parsimony. Total labor supply is equal to population, which is an exponential function. The secondary sector employment is defined as a residual of total population minus agricultural employment with the sectoral unemployment rates remaining fixed. The output demand is only implicitly specified through the marginal productivity of labor condition that sets the value of the marginal product of agricultural labor (i.e., quantity times the price of agricultural output) at a constant fraction of the marginal productivity of the secondary sector. Further refinements of the model which deal with topics such as the marketable surplus of food, agricultural exports in an open economy, and inputs of luxuries and of capital do not basically change the original theoretical scaffold.

Although Zarembka does not bring his model to its logical conclusion, he clearly points the way. This is a strong feature that guarantees the book will be taken serious note of by the scholar in the field. Chapter 1, for example, goes one step beyond Sen to reconcile the cleavage between the classical (Lewis, Fei-Ranis) and neoclassical (Jorgenson) models of labor surplus. By distinguishing between agricultural workers and work hours per worker, it is shown that the classical description of labor surplus obtains when the Sen conditions hold or when the elasticity of factor substitution between labor and land is zero. More important, it is also shown that the neoclassical position holds, and then it becomes unnecessary to distinguish between labor hours and agricultural workers, when the elasticity of indifferent substitution is equal to the elasticity of factor substitution. If the elasticity of indifferent substitution is greater than that of factor substitution and both are greater than zero and less than infinity, a middle solution between the classical and neoclassical description is appropriate. This analysis suggests that the question of labor surplus can only be handled by a combination of production analysis, that gives the parameters for factor substitution, and a utility maximization analysis of consumption that has as arguments leisure, agricultural goods, and which gives the parameters of indifferent substitution. I suggest that a transcendental logarithmic linear expenditure system would readily lead to the determination of the indifferent rates of substitution and to the complete specification of the labor market. This is a fruitful avenue for further research.

Another example of clearly pointing the way without carrying through is in chapter 8. Not unlike the work that, among others, Lau and myself have done, Zarembka uses the profit function to derive the output supply and the factor demand equations (and, incidentally, in an interesting appendix he generalizes the profit function for the three-factor CES production function). Nevertheless, this chapter also is left hanging, and no attempt is made to incorporate it into the central theme of the book. The profit function, which treats the prices of output and of variable factors of production as exogenous variables, accurately portrays the real world situation at the micro-level. Suppose one aggregates from the micro-profit function to get the macro-supply of output and demand for inputs. By superimposing next the aggregate demand for output and the aggregate supply of inputs, one has a general equilibrium solution with prices and quantities determined endogenously.

"This book grew out of the belief that a generally accepted theory of development has been lacking. Although one theory applicable to all developing countries may be unattainable, at least a theoretical framework should be possible. In attempting to provide such a framework, the book can be viewed as the analogue for developing countries of growth theory for developed countries" (p. vii). Zarembka has, happily, done less than promised, and there precisely lies the usefulness of the book. Should growth theory turn out to be a beautiful and rather pointless intellectual exercise, his book is still worth reading. It is true that at times he does pursue the chimerical visions of mathematical abstraction to their logical conclusion and beyond their usefulness. (Example: "A property of the mathematical solution obtained for the model is that the secondary sector is on its steady-growth path—i.e., the secondary sector capital/output ratio is behaviorally constant . . . [nevertheless], the model of the *economy*, as opposed to the sector, is not approaching its asymptote; that asymptote would imply that the ratio of rural to urban population approaches zero—which is exactly how growth theory treats the developed economy" (p. 3).) But there is much more than that. I have already mentioned chapters 1 and 8 as examples of bright insights. One could easily single out others in the same category such as chapter 4 on the theory of savings and chapter 10 on an econometric analysis of the food-consumption function. These also remain unincorporated in the main theme by suggesting sterling ideas that are dropped prematurely. I am reminded that the good teacher is not necessarily the one who answers questions and restores order but more so he who stirs the psyche and raises questions. This is the book of a good teacher.

Pan A. Yotopoulos
*Stanford University*

*Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address).*

# Books Received

**Adelman, M. A.,** *The World Petroleum Market,* Baltimore, The Johns Hopkins University Press for Resources for the Future, Inc., 1972, xviii + 438 pp. $5.95. Paper.

**Aurand, L. W., and A. E. Woods,** *Food Chemistry,* Westport, The AVI Publishing Company, Inc., 1973, vii + 363 pp. Price Unknown.

**Bain, Joe S.,** *Essays on Price Theory and Industrial Organization,* Boston, Little, Brown and Company, 1972, x + 227 pp. Price Unknown. Paper.

**Beneke, Raymond R., and Ronald Winterboer,** *Linear Programming Applications to Agriculture,* Ames, The Iowa State University Press, 1973, vii + 244 pp. Price Unknown.

**Bhagwati, Jagdish N., and Richard S. Eckaus,** eds., *Development and Planning: Essays in Honour of Paul Rosenstein-Rodan,* Cambridge, The MIT Press, 1973, 343 pp. $14.95.

**Borgstrom, Georg,** *Focal Points: A Global Food Strategy,* New York, Macmillan Publishing Co., Inc., 1973, xii + 320 pp. $8.95.

**Brandt, Hartmut, Bernd Schubert, and Egbert Gerken,** *The Industrial Town as Facator of Economic and Social Development: The Example of Jinja/Uganda,* Munchen, Weltforum Verlag, 1972, 451 pp. Price Unknown.

**Campbell, Keith O.,** *Agricultural Marketing and Prices,* Melbourne, Cheshire Publishing Pty. Ltd., 1973, ix + 148 pp. $3.95. Paper.

**Canny, M. J.,** *Phloem Translocation,* London, Cambridge University Press, 1973, x + 301 pp. $22.50.

**Chamberlain, Neil W.,** ed., *Contemporary Economic Issues,* rev. ed., Homewood, Richard D. Irwin, Inc., 1973, xiii + 352 pp. $4.95.

**Clayton, Kenneth C., and John M. Huie,** *Solid Wastes Management: The Regional Approach,* Cambridge, Ballinger Publishing Company, 1973, xvii + 140 pp. $12.50.

**Curry, Richard O.,** ed., *Radicalism, Racism, and Party Realignment: The Border States during Reconstruction,* Baltimore, The Johns Hopkins University Press, 1969, xxvi + 331 pp. $3.45. Paper.

**Downs, Anthony,** *Federal Housing Subsidies: How Are They Working?,* Lexington, D. C. Heath and Company, 1973, xv + 141 pp. Price Unknown.

**Downs, Anthony,** *Opening Up the Suburbs: An Urban Strategy for America,* New Haven, Yale University Press, 1973, ix + 219 pp. $7.95.

**Dwivedi, D. N.,** *Problems and Prospects of Agricultural Taxation in Uttar Pradesh,* New Delhi, People's Publishing House, 1973, xv + 228 pp. Rs. 25.00.

**Fried, Edward R., Alice M. Rivlin, Charles L. Schultze, and Nancy H. Teeters,** *Setting National Priorities: The 1974 Budget,* Washington, D. C., The Brookings Institution, 1973, xix + 446 pp. $3.95. Paper.

**Fuchs, Victor R., and Marcia J. Kramer,** *Determinants of Expenditures for Physicians' Services in the United States 1948–68,* Washington, D. C., National Bureau of Economic Research, 1972, vi + 63 pp. Price Unknown.

**Galbraith, John Kenneth,** *Economics and The Public Purpose,* Boston, Houghton Mifflin Company, 1973, xvii + 334 pp. $10.00.

**Gossling, W. F.,** *Productivity Trends in a Sectoral Macro-Economic Model: A Study of American Agriculture and Supporting Industries 1919–1964,* London, Input-Output Publishing Co., 1972, xxii + 296 pp. Price Unknown.

**Hailstones, Thomas J., Bernard L. Martin, and Frank V. Mastrianna,** *Contemporary Economic Problems and Issues,* 3rd ed., Cincinnati, South-Western Publishing Co., 1973, iv + 486 pp. Price Unknown. Paper.

**Haskell, Elizabeth H., and Victoria S. Price,** *State Environmental Management: Case Studies of Nine States,* New York, Praeger Publishers, 1973, xv + 283 pp. $16.50.

**Hightower, Jim,** *Hard Tomatoes, Hard Times,* Cambridge, Schenkman Publishing Company, 1973, xviii + 268 pp. $4.95. Paper.

**Hoben, Allan,** *Land Tenure among the Amhara of Ethiopia: The Dynamics of Cognatic Descent,* Chicago, The University of Chicago Press, 1973, xiv + 273 pp. $9.50.

**Inglett, George E.,** ed., *Symposium: Processing Agricultural and Municipal Wastes,* Westport, The AVI Publishing Company, Inc., 1973, xiv + 221 pp. $15.00.

**James, Gwyn,** *Agricultural Policy in Wealthy Countries,* Sydney, Angus and Robertson, 1971, xiii + 368 pp. £ 3.75. Paper.

**Kocher, James E.,** *Rural Development, Income Distribution, and Fertility Decline,* New York,

The Population Council, 1973, xiii + 105 pp. $3.95. Paper.

**Meloan, Clifton E., and Yeshajahu Pomeranz,** *Food Analysis Laboratory Experiments,* Westport, The AVI Publishing Company, Inc., 1973, vii + 143 pp. $8.00. Paper.

**Musgrave, Richard A., and Peggy B. Musgrave,** *Public Finance in Theory and Practice,* New York, McGraw-Hill Book Company, 1973, xv + 762 pp. $12.50.

**Neel, Richard E.,** *Readings in Price Theory,* Cincinnati, South-Western Publishing Co., 1973, vi + 554 pp. Price Unknown. Paper.

**Quaden, Guy,** *Parite Pour L'Agriculture Et Disparites Entre Agriculteurs,* La Haye, Martinus Nijhoff, 1973, xxii + 236 pp. Price Unknown.

**Reed, Gerald, and Henry J. Peppler,** *Yeast Technology,* Westport, The AVI Publishing Company, Inc., 1973, vi + 378 pp. $25.00.

**Richards, Audrey I., Ford Sturrock, and Jean M. Fortt,** eds., *Subsistence to Commercial Farming in Present-Day Buganda: An Economic and Anthropological Survey,* New York, Cambridge University Press, 1973, x + 336 pp. $22.50.

**Root, Franklin R.,** *International Trade and Investment: Theory, Policy, Enterprise,* 3rd ed., Cincinnati, South-Western Publishing Co., 1973, viii + 663 pp. Price Unknown.

**Seifert, William W., Mohammed A. Bakr, and M. Ali Kettani,** eds., *Energy and Development: A Case Study,* No. 25, Cambridge, The MIT Press, 1973, xix + 300 pp. $11.00. Paper.

**Shaw, Edward S.,** *Financial Deepening in Economic Development,* New York, Oxford University Press, 1973, xii + 260 pp. Price Unknown. Paper.

**Smith, Gerald W.,** *Engineering Economy: Analysis of Capital Expenditures,* 2nd ed., Ames, The Iowa State University Press, 1973, xii + 632 pp. $13.95.

**Upton, Martin,** *Farm Management in Africa: The Principles of Production and Planning,* New York, Oxford University Press, 1973, xiv + 341 pp. $17.75.

# Announcements

## 1974 ANNUAL AAEA MEETING

The 1974 Annual AAEA Meeting is scheduled for August 18–21 at Texas A&M University, College Station, Texas. The customary reception will be Sunday evening, August 18, and sessions will end Wednesday noon, August 21.

Dr. Clive R. Harston, Department of Agricultural Economics, Texas A&M University, is the Local Arrangements Chairman, and correspondence should be directed to his office concerning the meeting arrangements. Matters pertaining to the program should be directed to the Association President, Dr. Kenneth R. Tefertiller.

The program format will be one of general sessions and sectional meetings.

Dr. Joseph Coffey, Virginia Polytechnic Institute and State University, will serve as coordinator of the contributed papers sections. He will announce ground rules for the contributed papers in the near future.

Papers presented at the general session and sectional meetings will be published in the 1974 Proceedings issue (December 1974 AJAE). Contributed papers and discussions will be presented by title and author only in the Proceedings issue. Such papers may, of course, be submitted to the AJAE for standard editorial review and possible publication.

More detailed information on the program will be released soon.

## UNDERGRADUATE DEBATE, PUBLIC SPEAKING, AND ESSAY COMPETITIONS

Competition is open to any undergraduate student interested in agricultural economics. No individual student may enter both the debate and the public speaking competitions in the same year.

Individuals or chartered student section affiliates of the American Agricultural Economics Association must declare their intention of participating in either the public speaking or debate competition by writing *no later than June 1, 1974,* to Dr. Wayne D. Purcell, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma 74074.

### Public Speaking Competition

The public speaking may be on any topic in the area of agricultural economics. Each speech will be limited to 10 minutes' duration.

Chartered chapters or individuals must declare their intention of participating in either the public speaking or debate competitions by writing *no later than June 1, 1974,* to Dr. Lonnie L. Jones, Department of Agricultural Economics, Texas A&M University, College Station, Texas 77843.

### Debate Competition

The topic to be debated in 1974 will be announced directly to all the departments. Names of the contestants and/or alternatives and coaches, along with the mailing address of each, should be included with the declaration of intention to participate. No more than one debate team from one school may participate in the debate contest. To declare intention to participate, write to Dr. John Nixon, Department of Agricultural Economics, University of Georgia, Athens, Georgia 30601.

### Student Essay Contest

The essay contest does not require attendance at the AAEA's annual summer meeting. The development and preparation of a manuscript for purposes of publication is one of the objectives of this contest. Essays may deal with any topic in agricultural economics, agricultural industries, or rural sociology. The 1974 award paper will be published in the 1974 Proceedings issue.

Manuscripts should not exceed 2,500 words in length and should be prepared according to the instructions appearing on the inside back cover of the *American Journal of Agricultural Economics*. Manuscripts must be submitted in *triplicate by June 1, 1974,* to Dr. James G. Kendrick, Department of Agricultural Economics, University of Nebraska, Lincoln, Nebraska 68503.

## NOMINATING COMMITTEE FOR 1974–1975 AAEA OFFICERS

The following persons have been appointed by AAEA President Kenneth R. Tefertiller to serve on a committee to nominate persons to fill vacancies in the offices of the Association for the year beginning August 1974:

Emery N. Castle, Chairman
Charles L. Beer
Dale E. Butz
George E. Frick
James R. Gray
James R. Martin
John Sjo
Glen V. Vollmar.

Any member of the Association is eligible and is invited to submit suggestions for nominees to the chairman, Emery N. Castle, or to other members of the committee. Dr. Castle's address is the Graduate School, Oregon State University, Corvallis, Oregon 97331.

## VISITING LECTURER PROGRAM

The American Agricultural Economics Association is again conducting a Visiting Lecturer program for

1973–74. The Visiting Lecturer program is limited to those universities offering an undergraduate or master's degree, but not a Ph.D. degree. Since Association funds are not available to support the program, attempts are made to match the desire for a particular individual to give a lecture with the availability of that person to travel to the university.

The procedure works best where the college or university selects three or four specific agricultural economists they would like to have visit their school. The chairman contacts the selected individuals to see if they are available to give the requested lecture. Generally, dates are negotiated directly between the lecturer and the school from that point.

The chairman would be very happy to receive requests. Send the requests to R. J. Hildreth, Farm Foundation, 600 South Michigan Avenue, Chicago, Illinois 60605.

## SOUTHERN AGRICULTURAL ECONOMICS ASSOCIATION

The Southern Agricultural Economics Association will hold its annual meeting in Memphis, Tennessee, February 3–6, 1974. Dr. Verner G. Hurt, the Association's President, has planned an excellent program with prominent specialists for the invited sessions.

Regular membership in the SAEA is $6.00 per year, and junior membership (students) is $3.00 per year. To obtain further information or to enroll, write to Dr. James H. Simpson, Secretary-Treasurer of SAEA, Department of Agricultural Economics, Mississippi State University, State College, Mississippi 39762. Make checks payable to the Southern Agricultural Economics Association.

## REPORT FROM THE NORTHEASTERN AGRICULTURAL ECONOMICS COUNCIL

The annual meeting of the NAEC was held in Morgantown, West Virginia, June 25–27, 1973. Contributed papers as well as structured sessions made up the program.

Membership in the Council continues to grow, now totalling 250. This is made up of 231 paid members, eight libraries, and 11 Distinguished Life Members.

The membership has elected to sponsor a refereed journal. Two annual issues are planned. The Fall issue will reproduce the papers presented at our annual meeting. Manuscript submission deadline is May 1 with a publication date of September 1. The Spring issue will consist of contributed papers. Manuscript submission deadline is January 1 with a publication date about March 1. The editor is Dr. Robert L. Christensen, *Journal of the NAEC,* Department of Agricultural and Food Economics, 202 Draper Hall, University of Massachusetts, Amherst, Massachusetts 01002. Individuals interested in manuscript submission and individuals and institutions interested in subscribing should contact Dr. Christensen.

Annual dues are $5 for a regular membership and $3 for a student membership. Library or individual subscriptions to the *Journal* are the same as the current regular membership cost. Applications for membership and payment of dues or fees should be addressed to Dr. Daymon W. Thatch, Cook College, Rutgers University, New Brunswick, New Jersey 08903.

## NATIONAL EMPLOYMENT REGISTRY FOR AGRICULTURAL ECONOMISTS

A National Employment Registry for Agricultural Economists will be established in early 1974 to provide a central, nationwide clearinghouse for professional agricultural economists and employers. This experimental registry is being developed as a joint effort between the American Agricultural Economics Association and the Illinois State Employment Service. Funding for the project has been provided by a grant from the Manpower Administration, U. S. Department of Labor. The registry will be located in the Chicago Professional Office of the Illinois State Employment Service and will be staffed by experienced placement personnel. No registration, referral, or placement fees will be charged for this service.

The purpose of the registry is to facilitate a first-round of contact between professional agricultural economists and employers. The markets for agricultural economists represented by the employers may vary from such short and intermediate-term assignments as visiting professorships, sabbaticals, consultantships, and foreign assignments to longer term employment such as that sought by graduating B.S., M.S., and Ph.D. students. Employer groups may include academic institutions, business firms, government departments or organizations, and national and international agencies and foundations.

To facilitate placement of professional agricultural economists into these varied markets requires developing a profile of the profession's membership. All members of the agricultural economics profession, whether interested in a short-term assignment or longer-term employment (part or full time), are encouraged to register.

This computerized service will provide rapid and efficient matching of professional agricultural economists with job assignments. Employers using the service will submit job order forms to the registry office specifying characteristics of the job assignments as well as qualifications and requisites of candidates. This information will be used to generate lists of candidates matching the employers' specifications. Selection by this method will be solely on the basis of specified qualifications and interests and not upon subjective interpretation.

Employers seeking to hire agricultural economists whether on a long or short term basis are urged to list their vacancies and to utilize this source of recruitment for experienced personnel as well as recent graduates.

Changes in status or availability can be incorporated in the registrant's record at any time by

informing the registry office. Further, all registrants will be asked to review and update their registration records each spring.

It is contemplated that summary information will be made available to the profession to include such areas as general profile characteristics of the profession, number and type of jobs available, and starting salaries and overall characteristics of jobs and assignments filled.

Registration forms used by professional agricultural economists and employers are available upon request from the:

National Employment Registry for
Agricultural Economists
40 West Adams Street
Chicago, Illinois 60603
Phone: (312) 793-4904.

## STATISTICAL ANALYSIS SYSTEM

The Statistical Analysis System (SAS) for use on IBM 360-370 systems provides an integrated approach for the editing, summary, and statistical analysis of data with a major emphasis on ANOVA and least squares techniques. It uses a simple computer language to communicate to the computer what is to be done. The integrated approach used by SAS provides that whole sequences of operations can be done with a single entry of the set of data into the computer. It also provides the capability of extensive data file management and updating and general information retrieval. This is contrasted to the conventional statistical package that requires separate instructions to the computer and separate data entry for each procedure.

For more information concerning SAS, either technical or how you can obtain the system for your use, write Dr. Robert J. Monroe, Department of Statistics, North Carolina State University, Box 5457, Raleigh, North Carolina 27607.

## NEW JOURNAL

The *European Review of Agricultural Economics* is being published in English to serve as a forum for theoretical and applied agricultural economics research in Europe and to stimulate ideas regarding the economics problems of agriculture in Europe and other parts of the world. Publication was begun in 1973, and four issues per year are planned. Solicited are original articles, research notes, book reviews, comments on previously published articles, and news items about European agricultural economics activities. Also accepted will be full or abstracted articles which have been previously published in national publications and/or in other languages.

Inquiries should be directed to: Jan de Veer, Managing Editor, Landbouw-Economisch Instituut, Conradkade 175, The Hague, The Netherlands.

Subscriptions and single or back issues of the *European Review of Agricultural Economics* may be ordered through any bookseller or subscription agent or directly from the publisher, MOUTON, P. O. Box 482, The Hague, The Netherlands, or MOUTON, 7, rue Dupuytren, 75006 Paris, France.

## CONTRIBUTED PAPERS SESSION OF THE AAEA ANNUAL MEETING

Contributed papers relating to extension, teaching, research or business phases of the economics of agriculture, natural resources, and/or rural and community development will be considered. Tentatively, sessions are scheduled in the following topic areas:

1. General Agricultural Economics
2. Food and Consumer Economics
3. Agricultural Finance, Capital, Credit
4. Production Economics and Management
5. Natural Resource and Environmental Economics
6. Public Policy and Programs
7. Research Methodology
8. Demand, Supply and Price Analysis
9. International Trade and Foreign Development
10. Rural and Community Development
11. Extension Education
12. Agriculture and the Energy Crisis

Authors of contributed papers should submit the proposed titles to the Chairman of the contributed papers sessions by May 1. Finished manuscripts must be in the hands of the Chairman by June 15. Each manuscript must be accompanied by a 50 word abstract and a key word listing. Please follow *AJAE* manuscript guidelines. Each author should indicate the topic area in which he would like to present his paper. Because of scheduling problems, no individual will be scheduled to present more than one contributed paper at the meetings. Twenty to twenty-five minutes will be provided for the introduction, presentation, and discussion of each paper. Thus, papers should not exceed 12 pages double-spaced.

A fifty word abstract of papers presented in the Contributed Papers Sessions will be printed in the Proceedings Issue of the *AJAE*. Authors of contributed papers are invited to submit their manuscripts to the Editor of the *AJAE* to be considered for publication. Such manuscripts will be subject to the normal review process.

Chairman of the contributed papers sessions is:

Dr. Joseph D. Coffey
Department of Agricultural Economics
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Copies of the 50 word abstracts for the contributed papers will be available at registration and in advance of the session.

# News Notes

### THE AGRICULTURAL DEVELOPMENT COUNCIL, INC.

APPOINTMENT: **Hans P. Binswanger,** formerly with the University of Minnesota, as an associate.

### AGRICULTURE CANADA

APPOINTMENTS: **Wilfred V. Candler,** formerly with Purdue University, as director of the Farm and Rural Development Division, Economics Branch; **Brian H. Davey,** formerly with The University of Newcastle, Newcastle Upon Tyne, England, as economist with the Farm and Rural Development Division, Economics Branch.

### UNIVERSITY OF ARKANSAS

APPOINTMENT: **Robert Shulstad,** Ph.D. Oregon State, as assistant professor in resource economics and rural development.

### UNIVERSITY OF CALIFORNIA, DAVIS

APPOINTMENTS: **Carlos A. Benito,** Ph.D. California, Davis, as postgraduate research agricultural economist; **Robert McKusick,** Ph.D. California, Davis, as agricultural economist, NRED, USDA; **James G. Youde** as agriculturist, Agricultural Extension.

### THE UNIVERSITY OF CHICAGO

APPOINTMENT: **Theodore W. Schultz,** as a Governor of the Board, Government of Canada's International Development Research Centre.

### COLORADO STATE UNIVERSITY

APPOINTMENT: **Anthony A. Prato,** formerly with the University of Florida, as associate professor of economics.

REASSIGNMENTS: **Albert G. Madsen,** as agricultural marketing advisor with the Ministry of Agriculture, El Salvador, for two years beginning August 1973; **Richard G. Walsh,** one year with the Environmental Protection Agency, beginning August 1973.

### CORNELL UNIVERSITY

APPOINTMENTS: **Dennis U. Fisher,** assistant professor; **Thomas H. Stevens,** research associate.

AWARDS: **Daniel C. Sisler,** professor, received the State University of New York Chancellor's Award for Excellence in Undergraduate Teaching —the award carries a $500 prize; **Stanley W. Warren,** professor emeritus, received the 1973 D. Howard Doane Award from the American Society of Farm Managers and Rural Appraisers.

### ECONOMIC RESEARCH SERVICE

(CED, Commodity Economics Division; FDCD, Foreign Demand and Competition Division; FDD, Foreign Development Division; NEAD, National Economic Analysis Division; NRED, Natural Resource Economics Division.)

AWARD: **Richard S. Magleby,** FDD, received the USDA Merit Award for his work as marketing adviser to the U. S. Agency for International Development in Paraguay.

REASSIGNMENTS: **Nelson Bills,** from EDD to NRED, Ithaca, New York; **Wayne A. Boutwell,** CED-Blacksburg, Virginia, to Washington, D. C.; **Harold Casper,** NRED-Oxford, Mississippi, to Lincoln, Nebraska; **Ronald J. Glass,** NRED-Durham, New Hampshire, to Upper Darby, Pennsylvania; **James Hersfield,** NRED-Providence, Rhode Island, to Upper Darby, Pennsylvania; **Kenneth E. Nelson,** CED-Stillwater, Oklahoma, to Urbana, Illinois; **Rudie W. Slaughter,** CED-Washington, D.C., to Columbia, Missouri; **Roger P. Strickland,** CED, to Office of the Administrator, ERS, Washington, D.C.; **John Sutton,** NRED-Washington, D.C., to East Lansing, Michigan.

RETURN: **Richard S. Magleby,** FDD, from two and one-half years in Paraguay as marketing adviser to the U. S. Agency for International Development and the Paraguayan Minister of Agriculture.

### UNIVERSITY OF FLORIDA

APPOINTMENT: **James C. Cato,** Ph.D. Florida, as extension marine economist.

REASSIGNMENT: **Bobby Eddleman,** named director of the Center for Community and Rural Development at the University of Florida.

RESIGNATION: **Donald E. Long,** assistant professor, to Macomb, Illinois as a community development specialist with the University of Illinois Extension.

### UNIVERSITY OF GEORGIA

APPOINTMENTS: **Glenn C. W. Ames,** assistant professor; **W. Lanny Bateman,** assistant professor; **Neil R. Martin, Jr.,** agricultural economist, USDA; **Wesley N. Musser,** assistant professor.

RESIGNATIONS: **H. Evan Drummond,** assistant professor, to Oklahoma State University; **George K. Flaskerud,** assistant professor, to manage wheat farm in Minnesota.

*UNIVERSITY OF ILLINOIS*

LEAVES: **C. B. Baker,** sabbatical for six months ending March 31, 1974; **G. M. England,** sabbatical for six months ending January 31, 1974; **F. C. Fliegel,** sabbatical for six months ending May 31, 1974; **G. G. Judge,** sabbatical for six months ending June 30, 1974; **R. M. Leuthold,** sabbatical for six months ending June 30, 1974.

*UNIVERSITY OF KENTUCKY*

RETIREMENT: **John B. Roberts,** professor, September 1, 1973, after 37 years of service.

*THE UNIVERSITY OF MANITOBA*

LEAVE: **R. M. A. Loyns,** associate professor, one year ending September 1, 1974, appointment as research coordinator of Agricultural and Food System Research with the Food Prices Review Board, Ottawa.

*MICHIGAN STATE UNIVERSITY*

APPOINTMENTS: **Harold M. Riley,** professor, as chairman of the Department of Agricultural Economics; **Gerald D. Schwab,** Ph.D. Purdue, assistant professor for research and extension in farm management.

RESIGNATION: **Lawrence Witt,** to accept appointment with the Office of Economic Research and Analysis, Bureau of Intelligence and Research, U.S. Department of State, Washington, D.C.

*UNIVERSITY OF MINNESOTA*

APPOINTMENTS: **Martin E. Abel,** Professor, appointed director of the Economic Development Center; **Winston M. Grant,** M.S. Maine (Orono), research specialist; **Robert A. Hoppe,** M.A. Washington State, research specialist; **Harold E. Klein,** associate professor, as member of the Minnesota team in Tunisia; **Robert Reeser,** professor, appointed Party Chief for the Minnesota project in Tunisia; **Surjit S. Sidhu,** assistant professor, appointed under a University of Minnesota-Rockefeller Grant in cooperation with the University of Dar es Salaam, Tanzania, to develop a teaching and research program; **S. Thomas Stickley,** associate professor, as member of the Minnesota team in Tunisia; **Richard M. Todd,** B.A. Stanford University, research specialist; **Stephen J. Ziegler,** B.S. Minnesota, research specialist.

LEAVES: **Kenneth E. Egertson,** associate professor, to the University of Gadjah Mada, Indonesia, under the MUCIA-AID-Indonesian Higher Agricultural Education Project, from August through November 1973; **Walter L. Fishel,** associate professor, to the Agricultural Research Service, USDA, Beltsville, Maryland, for one year; **Frank J. Smith, Jr.,** professor, to the Farm Credit Administration, Washington, D.C., for the academic year 1973–74.

RESIGNATIONS: **Charles H. Cuykendall,** associate professor, to become manager and assistant vice president of the Security Trust Company in Hornell, New York; **Oscar M. Lund, Jr.,** research fellow, to the South Dakota State Planning Bureau, Pierre, South Dakota; **Vernon W. Ruttan,** professor, to become president, Agricultural Development Council, Inc. in New York.

*MISSISSIPPI STATE UNIVERSITY*

APPOINTMENTS: **Earl A. Stennis,** former president of East Mississippi Junior College, associate professor.

*THE UNIVERSITY OF NEBRASKA, LINCOLN*

APPOINTMENTS: **Duane A. Olsen,** as Extension economist; **Robert E. J. Retzlaff,** district farm management specialist at the Scottsbluff Experiment Station, Mitchell, Nebraska.

RETIREMENT: **Clifford Ashburn,** district extension specialist, retired July 1 from the Scottsbluff Experiment Station in Mitchell.

*UNIVERSITY OF NEVADA*

LEAVE: **John W. Malone, Jr.,** chairman of Agricultural and Resource Economics, to serve as director of Program Planning in the Chancellor's office of the University system, for the remaining part of this academic year.

*OHIO STATE UNIVERSITY*

APPOINTMENT: **Douglas Graham,** associate professor.

RETIREMENT: **Margaret McDonald,** associate professor, after 44 years with the department.

RETURN: **Richard Meyer,** after a three-year assignment with USAID in Brazil.

*OKLAHOMA STATE UNIVERSITY*

APPOINTMENTS: **Clint E. Roush,** instructor and farm management specialist; **Michael S. Salkin,** Ph.D. California, Davis, research assistant.

REASSIGNMENT: **Robert E. Daugherty,** livestock marketing specialist, to serve for 18 months with a special livestock team in Teran, Iran.

*OREGON STATE UNIVERSITY*

APPOINTMENTS: **Ludwig M. Eisgruber,** formerly with Purdue University, professor and head of the Department of Agricultural Economics; **Sheng Hui Liao,** research associate.

HONORS: **Jean B. Wyckoff,** professor, **Dennis U. Fisher,** assistant professor, and **Marion D. Thomas,** professor, Western Agricultural Economics Association Award for Outstanding Extension Program; **Charles S. Kang,** student, Agricultural Economics Association Award for Outstanding Masters Thesis; **Dick Wedin,** student, American Agricultural Economics Association National Essay Competition Award; **Herbert**

H. Stoevener, professor, Joe B. Stevens, associate professor, Howard F. Horton, professor, Adam A. Sokoloski, EPA (Washington, D. C.), Loys P. Parrish, EPA (Cincinnati), and Emery N. Castle, professor, American Agricultural Economics Association and Western Agricultural Economics Association Published Research Awards.

LEAVES: **Russell C. Youmans**, associate professor, one year at Indiana University, Bloomington; **Clinton B. Reeder**, assistant professor, one year study leave at the University of Oregon.

*PURDUE UNIVERSITY*

APPOINTMENTS: **David L. Debertin**, temporary assistant professor; **Paul L. Farris**, professor, appointed Acting Head of the Department of Agricultural Economics; **Valerie H. Justice**, temporary instructor; **Elizabeth A. Maxwell**, temporary instructor; **George F. Patrick**, temporary assistant professor; **Anne E. Peck**, assistant professor; **J. B. Penn**, ERS, NEAD, USDA, assistant professor; **Bruce H. Wright**, formerly with ERS, NEAD, USDA-Washington, D.C., to Purdue with ERS, NEAD, USDA as associate professor.

LEAVES: **Karl W. Kepner**, one year, to Washington State University and Creative Management Institute, St. Louis, Missouri; **Wilford H. M. Morris**, one year, to Regional Economic Service, USAID, Abidjan, Africa; **Don Paarlberg**, continuation for one year as director, Agricultural Economics, USDA; **Robert C. Suter**, one year, to Indiana School of Law, Indianapolis, University of Chicago, and Northwestern University.

REASSIGNMENT: **Charles E. French**, professor and former Head of Department of Agricultural Economics, has stepped aside to pursue teaching and research interests within the department.

RESIGNATIONS: **Lawrence J. Brainard**, to Economic Research Department, Chase Manhattan Bank, New York, as director of economic research on socialist countries; **Ronald D. Knutson**, to Farmer Cooperative Service, USDA, as administrator; **Henry A. Wadsworth, Jr.**, to Cooperative Extension Service, Cornell University, as associate director.

RETURNS: **William S. Farris**, professor, after one year with the Farmer Cooperative Service, USDA; **Lee F. Schrader**, professor, after one year at Harvard University in cooperation with the Farmer Cooperative Service, USDA.

*SOUTH DAKOTA STATE UNIVERSITY*

APPOINTMENTS: **Thomas Daves**, formerly on assignment in Tunisia for the University of Minnesota; **Robert Vertrees.**

*TENNESSEE TECHNOLOGICAL UNIVERSITY*

APPOINTMENT: **David B. Narrie**, Ph.D. Virginia Polytechnic Institute and State University, assistant professor.

*THE UNIVERSITY OF TENNESSEE*

APPOINTMENT: **John R. Brooker**, Ph.D. Florida, assistant professor; **Larry C. Morgan**, assistant professor; **Mervin J. Yetley**, assistant professor.

RETIREMENT: **B. D. Raskopf**, associate professor, August 31, 1973.

RETURN: **James G. Snell**, after one year with FAO in Iran.

*UTAH STATE UNIVERSITY*

LEAVE: **Morris Whitaker**, assistant professor, to La Paz, Bolivia with the USAID/Utah State team for two years.

RETURNS: **Lloyd Clement**, associate professor, after two years with the USAID/Utah State team in La Paz, Bolivia; **Roger A. Sedjo**, assistant professor, after working as an AID economist for two years in Korea and one year in Washington, D.C.

*VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY*

HONORS: **Charles W. Coale** and **Don L. Long**, for their Marine Economics workshop, the American Agricultural Economics Association Distinguished Extension Award for Professional Excellence.

*VIRGINIA STATE COLLEGE*

APPOINTMENT: **Richard G. Milk**, formerly with Northwestern Louisiana University, as associate professor of economics.

*UNIVERSITY OF WISCONSIN*

REASSIGNMENT: **Glen Pulver** resigned effective January 1, 1974, as Dean of the Division of Economic and Environmental Development and will return to the Department of Agricultural Economics to work in community development Extension.

*UNIVERSITY OF WYOMING*

APPOINTMENTS: **Dale Menkhaus**, Ph.D. Purdue, assistant professor.

*OTHER APPOINTMENTS:*

**David G. Barton**, Ph.D. Purdue, assistant professor, Cornell University.

**Harold Beebout**, Ph.D. Wisconsin, economist, The Urban Institute, Washington, D.C.

**Surapon Brahamkasikara**, M.S. Arkansas, returned to Thailand as supervisor of farm groups in Uhol Rajatani Province.

**Marshall Burkes**, promoted to Director of the Office of Finance for the Federal Home Loan Banks.

**Ying-Chih Chiang**, Ph.D. Virginia Polytechnic Institute, associate professor, National Taiwan University.

**Mark Dadd**, Ph.D. Wisconsin, Ministry of Agriculture, London, England.

**Pio Elevazo**, M.S. Arkansas, returned to the Re-

public of the Philippines to continue work at the Mindanag Institute of Technology, Kabacan, Cotabato.

**James W. Fisher,** M.S. Arkansas, the Bank for Cooperatives, St. Louis, Missouri.

**John A. Ginzel,** Ph.D. Purdue, economist, Madigan-Abraham, Sarasota, Florida.

**David H. Harrington,** Ph.D. Purdue, agricultural economist, Canada Department of Agriculture, Ottawa, Ontario.

**Fernando A. Hernandez-Lohr,** M.S. Purdue, marketing analyst, Asosiacion de Organismos de Agricultores, Hermosillo, Sonora, Mexico.

**Larry D. Jones,** Ph.D. Purdue, assistant professor, University of Kentucky.

**George F. Kennedy,** Ph.D. Purdue, to Vancouver, British Columbia, Canada.

**Rodney C. Kite,** Ph.D. Purdue, agricultural economist, ERS, USDA, Washington, D.C.

**Ralph G. Lattimore,** Ph.D. Purdue, economist, Economics Division, Ministry of Agriculture, New Zealand.

**Anthony C. Lewis,** Ph.D. Purdue, senior research officer, Massey University, Palmerston North, New Zealand.

**Wen Rong Lin,** Ph.D. California, Davis, economist, Department of Natural Resources, Washington.

**Allan E. Lines,** Ph.D. Purdue, research associate, Miner Institute, Cornell University, Chazy, New York.

**Don McClatchy,** Ph.D. Purdue, economist, Canada Department of Agriculture, Ottawa, Ontario.

**Michael M. Mickett,** promoted to Deputy Director of the Office of Finance for the Federal Home Loan Banks.

**Charles E. Overton,** Ph.D. Purdue, agricultural economist, NEAD, USDA, Washington, D.C.

**Peter K. Pollak,** Ph.D. candidate Minnesota, Departmento de Economia Agricola, Universidate Federal do Ceara, Brazil.

**Thomas R. Quinn,** M.S. Purdue, Youth Agent, Kokomo, Indiana.

**Robert A. Richardson,** Ph.D. Purdue, lecturer, Faculty of Economic Studies, University of New England, Armidale, N.S.W., Australia.

**John Rosine,** Ph.D. Wisconsin, Federal Reserve Bank, Minneapolis, Minnesota.

**John H. Sanders,** Ph.D. Minnesota, Departmento de Economia Agricola, Universidate Federal do Ceara, Brazil.

**John Schmidt,** promoted to manager, Investment Division, Office of Finance for the Federal Home Loan Banks.

**W. Ed Schmisseur,** Ph.D. Purdue, assistant professor, Oregon State.

**John Sherrod,** former director of the National Agricultural Library, now vice president of Informatics, Inc., Canoga Park, California.

**Brian D. Spurlock,** M.S. Arkansas, office management trainee, General Services Administration, Washington, D.C.

**Tyler R. Sturdevant,** formerly USAID Agricultural Statistics and Sampling Advisor in Pakistan, appointed Assistant Division Chief for Research and Methodology, Business Division, U. S. Census Bureau, Washington, D.C.

**Wesley Weidemann,** Ph.D. Wisconsin, Visiting Rockefeller Lecturer, Department of Agricultural Economics and Extension, University of Ibadan, Ibadan, Nigeria.

**Mitoshi Yamaguchi,** Ph.D. Minnesota, assistant professor, Department of Economics, Kobe University, Kobe, Japan.

## OBITUARIES

**George T. Blanch,** 71, Emeritus Professor, Utah State University, died March 21, 1973, in Salt Lake City, Utah.

He received his B.S. and M.S. degrees from Utah State University and was awarded his Ph.D. from Cornell University. In 1934 he joined the agricultural economics department of Utah State University and was appointed head of the department in 1952, a position he held until his retirement. He served several short term assignments with the Bureau of Reclamation and spent several months in Turkey and Greece as an economic advisor for the Harza Engineering Company.

From 1958–60 he was on an assignment, accompanied by his family, in Iran, where he was an economic advisor for the Karadg Agricultural College. He had served as president of Utah State University Faculty Association and of the Utah Conference of Higher Education. He was joint author and author of 66 scientific publications and technical bulletins in the areas of farm management and resource economics.

He is survived by his wife Eva Baxter Blanch, two sons, one daughter, and seven grandchildren.

**Walter H. Ebling,** 81, former state agricultural statistician and Emeritus Professor at the University of Wisconsin-Madison, died May 2, 1973, after a brief illness.

Ebling began a 33 year career with the Wisconsin crop and livestock reporting service in 1926 and was named agricultural statistician in charge of the Wisconsin office of the Federal Crop and Livestock Estimates Service in 1929. He developed a state system of data collection not provided for under the federal reporting program and pioneered issuance of farm statistic reference bulletins for all counties in Wisconsin (the first county farm bulletins). He held a part-time teaching appointment in the University of Wisconsin and taught agricultural data problems and methods between 1936 and 1962. In 1951 he received the Distinguished Service Award from the USDA for his work in the area of agricultural statistics. Professor Ebling was named an honor-

ary life member of the Wisconsin Agricultural Extension Workers Association in 1961, and in 1967 the Wisconsin State Board of Agriculture adopted a formal resolution recognizing his long and distinguished service to Wisconsin and the nation.

**Rodney R. Paul,** 32, USDA economist, died on September 8 at Ames, Iowa. He had been afflicted with a chronic heart condition for the past several years.

Despite his young age, Rodney had earned the respect and admiration of his colleagues for his competence and conscientiousness as a member of the FPE field staff at Ames.

Mr. Paul had been working as a member of the oil crops program area and shortly before his death had come to Washington to complete his assignment as part of a special task force requested by Secretary Butz.

Rodney is survived by his wife, Carol, and three children

**William Temple Wesson,** 58, USDA economist, died while at work in Washington, D. C., on October 26, 1973.

Wesson came to the Department in 1954 from the Brookings Institution where he had served since 1950 as a research assistant on a study of futures trading in agricultural commodities.

Born in Virginia, he received his education at North Carolina State University and the University of Chicago. Before going to The Brookings Institution, he worked for the N. C. State Department of Agriculture in crop reporting. While with USDA he authored or co-authored more than 30 monographs, articles, and staff studies relating to the economics of futures trading. He also prepared a number of historical studies of selected cost components in marketing margins.

Mr. Wesson is survived by his wife, Susie Merle Wesson, of Temple Hills, Maryland; three children his mother; two brothers; and four grandchildren.

# AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

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*Volume 56 Number 3*
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# An Empirical Test of Utility vs. Profit Maximization in Agricultural Production*

WILLIAM LIN, G. W. DEAN, AND C. V. MOORE

**Production economics literature contains many studies which assume that the producer's goal is to maximize profits. This study tests the hypothesis that Bernoullian and lexicographic utility are more accurate predictors of farmer behavior than profit maximization. Six large California farms were used to test the hypothesis. After-income tax *E-V* (expectation-variance) boundaries were developed for each farm and utility, and profit maximizing crop plans were determined for each. A goodness-of-fit criterion showed that Bernoullian utility formulations provided the greatest accuracy in predicting actual and planned crop patterns, followed by the lexicographic formulation. Profit maximization showed the poorest predictive power.**

***Key words:*** **utility theory; Bernoullian; lexicographic; risk; income taxes.**

THERE IS NOW ample literature which purports to test the "economic rationality" of agricultural producers [e.g., 3, 10, 12, 15, 21, 22] based on Cobb-Douglas production functions fitted to cross-section data. Such studies generally conclude that producers, even in the most backward areas, act as profit maximizers within their technological and institutional constraints. Thus, the hypothesis that "there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture" [19, p. 37] generally is not rejected.

A more detailed examination of such studies, however, reveals some serious drawbacks. First, within the production function framework, farm-by-farm tests of efficiency ($MVP =$ resource price) generally show a much greater misallocation of resources than is revealed by average resource use over the sample. As Massell and Johnson [15] emphasize, profit-maximizing resource use on the average farm is a necessary but not sufficient condition for profit-maximizing behavior on individual farms. Yet the latter is a necessary condition to achieve efficient resource allocation. In fact, empirical studies explicitly employing the profit maximization hypothesis (e.g., in linear programming studies of individual farm and aggregate supply response) have generally provided results inconsistent with observed or plausible behavior [e.g., 1, 4]. Second, the typical production function study, with few exceptions, is based on a sample of firms whose output mix is fairly heterogeneous. It is the authors' suspicion, to be explained subsequently, that the results in such cases are largely spurious. Third, the traditional production function approach takes prices and technology as given (riskless), and profit maximization as an appropriate expression of producer behavior. Dillon and Anderson [5] recently attempted to incorporate risk considerations (technical uncertainty) into the appraisal of resource allocation efficiency through the estimation of "expected loss." They also emphasize the need for investigation of alternative behavioral hypotheses, such as expected utility maximization.

The objective of this study is to provide a test of predicting individual producer behavior within a framework which corrects many of the deficiencies noted above. Production functions are estimated for individual crops, rather than for a heterogeneous aggregate; technical and price risk for each crop are included; finally, the farmer's subjective attitude toward risk is approximated by utility functions estimated through personal interviews. The guiding hypothesis is that inadequate treatment of risk has been a major factor accounting for the discrepancy between actual and predicted (profit maximizing) individual behavior in past studies. Given the specific risk framework to be developed below, it is hypothesized that farmers' operational decisions are more consistent with utility maximization than with profit maximization. For comparison, three alternative decision criteria are tested: profit maximization, maximization of Bernoullian utility, and maximization of utility in a lexicographic context.

* Giannini Foundation Paper No. 371. The perceptive comments of Gordon A. King have improved the quality of the paper.

WILLIAM LIN *is economist with the Department of Natural Resources, Olympia, Washington.* G. W. DEAN *(deceased) was professor of agricultural economics and agricultural economist in the Experiment Station and on the Giannini Foundation, University of California, Davis.* C. V. MOORE *is agricultural economist, Economic Research Service, U. S. Department of Agriculture, stationed at University of California, Davis.*

## Utility vs. Profit Maximization

The basis for reservations about the aggregate production function approach and its disregard for risk is illustrated in Figure 1. Suppose that firms in the sample can produce potatoes, corn, or wheat. Further, suppose that firm A specializes in potatoes (a), B in corn (b), and C in wheat (c), and that each is produced with a technically efficient, fixed factor proportions production function.[1] Converting the output of each firm to value by the normal production function aggregation procedure, firms A, B, and C all produce $10,000 worth of output with different factor proportions and fall nicely on isoquant *abc*. Suppose the input price ratio is given by line *PP* (constant for all three firms). Then, firms A and C are judged to be "price inefficient" [7], even though they are technically efficient. Suppose now that another firm D is observed producing $10,000 of output with a combination of one-fourth potatoes and three-fourths wheat. Firm D is then judged to be technically inefficient—a strange result since both potatoes and wheat are produced individually in a technically efficient manner.

The "economic inefficiency" (arising from technical inefficiency, price inefficiency, or both) of firms A, C, and D, according to production function studies may be due to the following: first, one factor of production fixed in the short run (e.g., if $K$ is fixed at $K_1$, firm C may be setting $MVP_1 = P_1$ at point $c$), or second, because each firm faces different factor prices (e.g., a price line $P'P'$ for firm A). Once "corrected" for such variables, the behavior of the individual firms is said to be relatively well explained by the profit maximization assumption. However, the above rationalizations for firms A and C cannot be extended easily to firm D—the case of a multiple product firm. Interestingly, the published cases which show behavioral results significantly different from the profit-maximizing assumption frequently include multiple-product production functions.

Now suppose that risk (measured in terms of the variance of crop net income) is highest for potatoes, moderate for corn, and lowest for wheat. Suppose further that the expected net incomes of the three enterprises rank in the same order—from a high for potatoes to a low for wheat (e.g., assuming price line $PP'$). Utilizing the *E-V* (expectation-variance) decision framework, suppose that $a$, $b$, and $c$ all fall on a mean-variance (*E-V*) boundary.[2] Even point $d$ might fall on the *E-V* boundary somewhere between $b$ and $c$. If so, all points observed are "efficient" in an *E-V* sense, and all producers could be "rational" in the sense that they maximize utility with different utility functions. For example, in Figure 2, the operator of firm D (producing 1/4 potatoes and 3/4 wheat) would choose $d$ over $b$ since his indifference curve ($U_D$) indicates that he is a relatively strong risk-averter. Since the operator of firm B (specializing in corn) is less risk-averse (indifference curve $U_B$), he would

[1] In California attempts to fit Cobb-Douglas production functions to samples of farms specializing in a single crop have failed because inputs were used in essentially fixed proportions. This limited range of input substitution in the production of a *single* product in a homogeneous region holds quite generally.

[2] The *E-V* framework for decision making under risk includes two components: (1) an *E-V* boundary, or "frontier," defined as a locus of points showing alternative production plans with a minimum variance of income for given levels of expected income, and (2) the decision maker's (risk averse) utility function from which is derived a family of indifference curves in an *E-V* space. The decision maker's utility-maximizing plan corresponds to the tangency of the *E-V* boundary with an indifference curve. Figure 2 provides a typical example of the *E-V* framework.

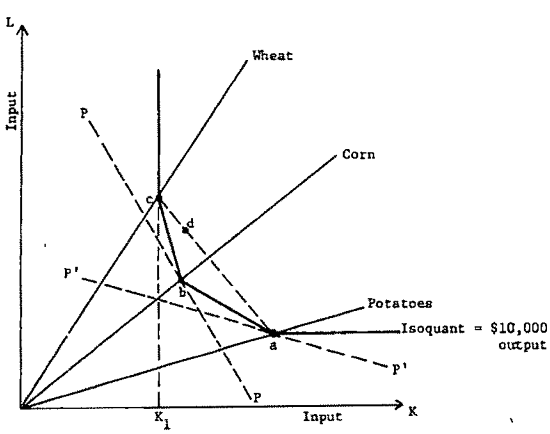


**Figure 1. Multiple-product production function**

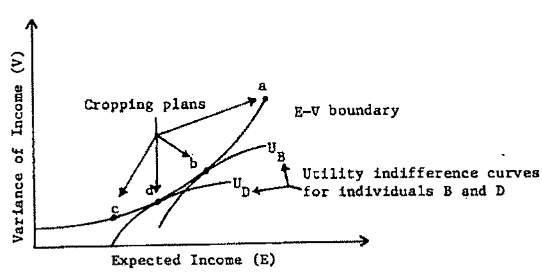


**Figure 2. Expected utility maximization in an *E-V* framework**

choose $b$ over $d$. Both are rational in the sense of maximizing their utility under risk.

Theoretically, utility maximization is more attractive than profit maximization in that (1) it can explain why two individuals, faced with exactly the same situation, might rationally respond quite differently, and (2) it does not exclude profit maximization but rather includes it as a special case of Bernoullian utility. Tentative support for the utility maximization hypothesis, based on a sample of Australian wool producers, was reported earlier in this *Journal* by Officer and Halter [16]. The current study complements this earlier investigation by extending the analysis to a different set of producers (large California farmers) and by examining lexicographic utility functions as well as Bernoullian utility functions and profit maximization. Lexicographic utility was included primarily on the grounds that it can easily incorporate multiple goals, whereas Bernoullian utility concentrates only on attitudes toward risk.

## Selection of Farms and Test Procedures

The authors reasoned that the utility hypothesis could be subjected to a particularly rigorous test on large-scale California farms—i.e., in situations where the profit maximization hypothesis appeared *a priori* to be quite valid. Thus, six case study farms—three family partnerships varying from 2,200 to 3,000 irrigated acres and two corporations and a non-family partnership varying from 7,500 to 26,500 irrigated acres—were selected for intensive analysis. All six farms were located in an area (Westside, San Joaquin Valley) where high water costs have forced a careful analysis of high-value, high-risk alternatives such as fruit, nut, grape, and vegetable production. All had ample access to capital so that risk preference rather than external capital rationing appeared predominant in crop selection decisions.

The procedure for testing the predictive power of utility maximization relative to profit maximization included four essential steps:

1. Derivation of the mean-variance ($E$-$V$) frontier of cropping systems for each farm.
2. Derivation of Bernoullian and lexicographic utility functions for the major decision-maker in each unit (the major partner or manager in each of the four partnerships and the hired manager of each of the two corporations).
3. Derivation for each farm of the three cropping systems along the $E$-$V$ boundary which maximized, respectively, Bernoullian utility, lexicographic utility, and expected profit.
4. Comparison of the accuracy of the three alternative maximization hypotheses (Bernoullian utility, lexicographic utility, and expected profit) in predicting the *actual* and *planned* cropping system of each farm.

## Derivation of the $E$-$V$ Frontiers

The $E$-$V$ frontier for each farm shows a set of alternative production plans, each providing minimum net income variance for specified levels of expected net income. Empirically, the $E$-$V$ frontier for each farm was efficiently derived using the following quadratic programming (QP) model:

$$\begin{aligned} \text{maximize } & Z = C'X - 1/2X'QX \\ \text{subject to } & AX \leqslant b \\ & C'X = k \\ & X \geqslant o \end{aligned}$$

where

$Z$ = value of the objective function,
$X$ = a column vector of levels (acreages of individual crop activities),
$C'$ = a row vector of expected "net returns" per acre of individual crop activities,
$1/2Q$ = a variance-covariance matrix of net returns of individual crops,
$A$ = a matrix of input-output coefficients for each crop,
$b$ = a vector of constraints including land in four time periods, annual and peak season water supplies and cotton and sugar beet allotments, and
$k$ = a constant indicating total expected net return; $k$ was varied parametrically from zero to a maximum possible value, thereby tracing out the minimum income variance for each level of expected income.

In the spirit of the Bayesian approach, the decision-maker's subjective probability distributions of price and yields were incorporated, insofar as possible, in the estimation of the expected net return vector ($C'$) and the variance-covariance matrix of net returns ($1/2Q$). Sub-

jective probabilities were used to simulate as closely as possible the decision-maker's view of his own individual decision environment and to avoid the downward aggregation bias caused by the use of county or state price and yield series to estimate individual farm variability [2]. In fact, when prices and yields were combined with cost data, the net income variances based on subjective probability (those used in this study) exceeded those estimated from aggregate time series data in 90 percent of the cases.

While the means and variances of net income for individual crops on each farm were estimated subjectively, it proved impossible to obtain subjective estimates of covariances (or correlations) directly from the farmers. Neither was it possible to use directly the historical covariances among crops since these, when combined with subjective variances, led to inconsistencies revealed by a variance-covariance matrix that was not positive semi-definite. Thus, to generate estimates of covariances, time series of net incomes for each crop were reconstructed by expressing the historical trend-corrected net incomes for each crop in terms of standard normal deviates about the mean, then substituting the standard deviations derived from the subjective net income distributions. Calculation of the variance-covariance matrix from this reconstructed set of time series data preserved the subjective net income variances, incorporated the historical relationships *among* crops, and guaranteed a positive semi-definite matrix.

A quadratic programming (QP) model for each farm provided an estimate of the ("before tax") $E$-$V$ boundary for that farm.[3] Moving up the $E$-$V$ frontier, the cropping system changed from entirely field crops to ones dominated by trees, vines, and fresh vegetables.[4] Given the extremely high levels of potential income, however, the realistic decision environment for producers clearly should include income taxes. Thus, the $E$-$V$ curve for each farm was corrected to an "after tax" basis, utilizing the 1972 income tax regulations (progressive tax rate, income averaging, loss-carry forward and backward, maximum tax on earned income, and capitalization of citrus and almond orchard development costs).

While an "after tax" $E$-$V$ boundary might conceivably be derived by explicitly introducing the various income tax regulations into a QP model, such a procedure would be almost hopelessly complicated. Thus, the "before tax" $E$-$V$ boundary for each farm was converted to an "after tax" basis by a Monte Carlo simulation involving the following steps:

1. For a given $E$-$V$ point on the "before tax" frontier, simulate $n$ years ($n = 30$ to 120) of incomes with that $E$ and $V$ (the greater the variance, the larger the required value of $n$).
2. Apply the relevant income tax provisions to that series, thereby deriving a new series of "after tax" incomes.
3. Calculate the "after tax" $E$ and $V$ from the new series, providing one point on the "after tax" $E$-$V$ frontier.
4. Repeat steps 1 and 3 for a series of $E$-$V$ points, tracing out the entire "after tax" $E$-$V$ frontier.

As hypothesized, and as illustrated later for farm 1 in Figure 3, inclusion of income taxes changed both the level and curvature of the $E$-$V$ frontier. The "after tax" $E$-$V$ frontiers were used exclusively in the tests of utility and profit maximization.

## Derivation of Utility Functions

### Bernoullian utility

The Ramsey model, modified somewhat as explained below from that used by Officer and Halter [16], was used in deriving the Bernoullian utility functions. Each decision-maker was asked to "play" a series of nine "games against nature" of the following type (game 1):

| State of Nature | Action $A_1$ | $A_2$ | $P(\theta_i)$ |
|---|---|---|---|
| $\theta_1$ | $a$ | $b$ | 1/2 |
| $\theta_2$ | $y$ | $x$ | 1/2 |

[3] See Figure 3 for an example of the "before tax" $E$-$V$ boundary. The $E$-$V$ boundary solutions were obtained on the IBM 1130 using a quadratic programming routine developed by Prof. James N. Boles, Department of Agricultural Economics, University of California, Berkeley.

[4] Since trees and vines are perennial crops requiring a long-term investment, there is some question of whether they should be included in a model along with annual crops. In this study, the expectation ($E$) and variance ($V$) of the annual annuity value of trees and vines were calculated and compared directly with annual crops. We recognize that this simplification ignores special problems such as heavy cash flow requirements, lack of flexibility once planted, and other factors beyond $E$ and $V$ which might influence decisions. To the extent that these other factors dominate, our results will be distorted.

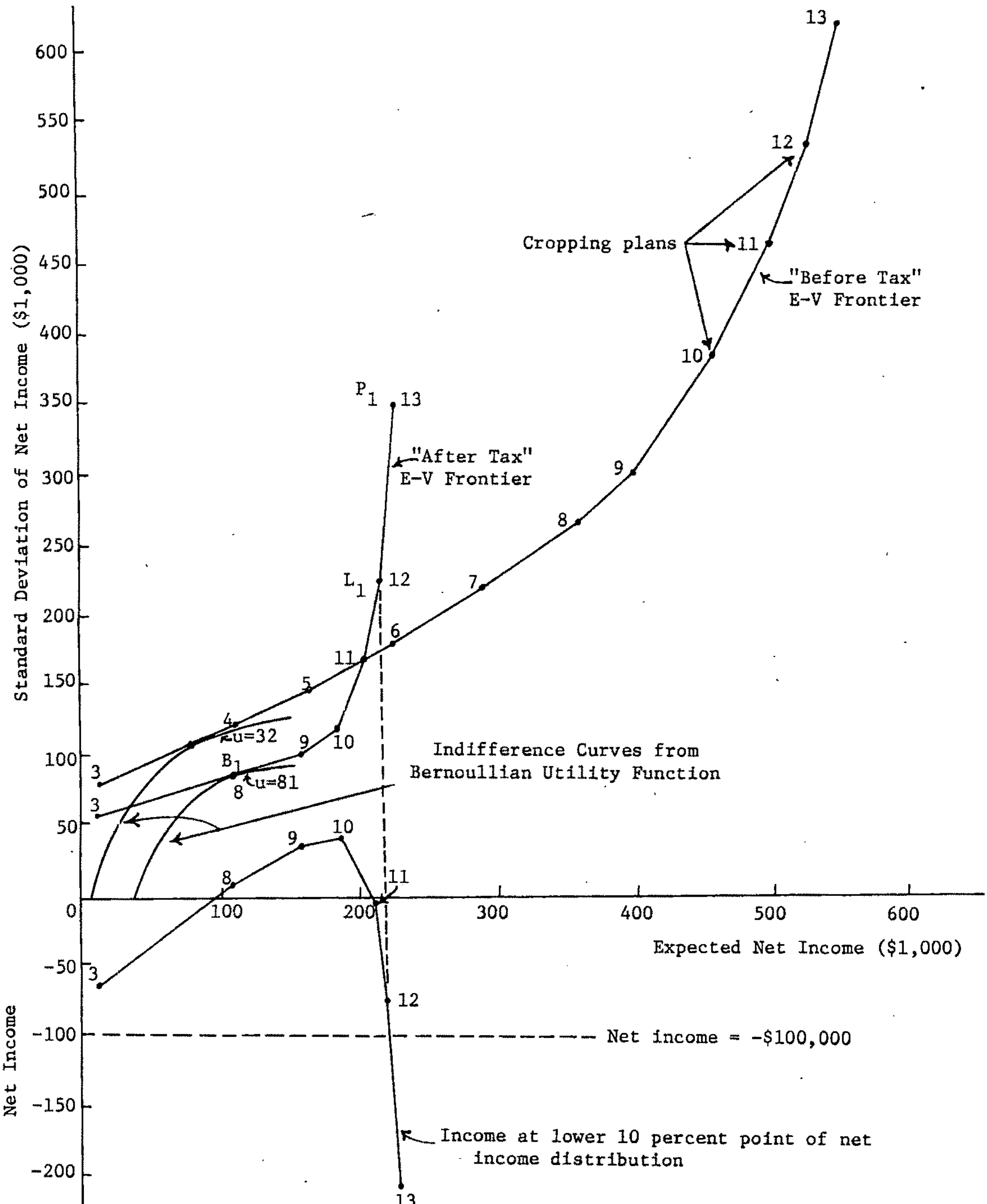


Figure 3. Illustration of Bernoullian and lexicographic maximization, farm 1

Outcomes $a$, $b$, and $x$ are pre-assigned "payoffs" ($a > b > x$), presented to the farmers as alternative levels of net farm income. Assuming that the two states of nature $\theta_1$ and $\theta_2$ (explained to the farmers as alternative sets of "favorable" and "unfavorable" economic conditions) are equally likely (i.e., with "neutral" probabilities of one-half each), the subject was asked to specify the monetary value (net income) of the outcome $y$ such that he would be indifferent between

actions $A_1$ and $A_2$.[5] With this particular value of outcome $y$,

$$(1) \quad u(a) + u(y) = u(b) + u(x),$$

or

$$(2) \quad u(a) - u(b) = u(x) - u(y) = K_1.$$

That is, the utility interval ($K_1$) between monetary values $a$ and $b$ equals that between $x$ and $y$. A second game is now played, as follows:

| State of Nature | Actions $A_1$ | Actions $A_2$ | $P(\theta_i)$ |
|---|---|---|---|
| $\theta_1$ | $b$ | $c$ | 1/2 |
| $\theta_2$ | $y$ | $x$ | 1/2 |

Outcomes $b$, $x$, and $y$ are given from game 1, and the individual is asked to select the "indifference value" of $c$. Again,

$$(3) \quad u(b) + u(y) = u(c) + u(x),$$

or

$$(4) \quad u(b) - u(c) = u(x) - u(y) = K_1.$$

Therefore, from equations (2) and (4):

$$(5) \quad u(a) - u(b) = u(b) - u(c) = K_1.$$

Given monetary values for $a$, $b$, and $c$, it is possible to derive, through a series of additional games (3, 4, 5, . . . ), monetary values ($d$, $e$, $f$, . . .) which maintain the same constant utility $K_1$ between successive pairs of monetary values.

From the data generated by the successive games (nine in this case), the following simultaneous equation system is obtained:

$$\begin{aligned} u(a) - u(b) &= K_1 \\ u(b) - u(c) &= K_1 \\ u(c) - u(d) &= K_1 \\ &\vdots \\ u(i) - u(j) &= K_1. \end{aligned}$$

To solve this system of nine equations in 11 unknowns, the authors assigned arbitrary utility values to outcomes $a$ and $b$—$u^*(a)$ and $u^*(b)$, respectively.[6] The utility interval $K_1$ and the utility values corresponding to monetary values $c$, $d$, . . . , $j$, can then be derived, the points plotted, and regression equations (estimated utility functions) fitted to the derived points. For example, setting $a = \$90{,}000$, $b = \$50{,}000$, and $x = \$0$, respectively, in game 1, suppose the subject chooses an "indifference value" of $y = -\$20{,}000$. Then, from equation (2), $u(\$90{,}000) - u(\$50{,}000) = u(\$0) - u(-\$20{,}000) = K_1$. Arbitrarily setting $u(a) = u(\$90{,}000) = 100$ utiles and $u(b) = u(\$50{,}000) = 75$ utiles, then $K_1 = 25$ utiles. Suppose the subject now chooses an "indifference value" for $c$ of \$30,000 in game 2. From equation (5),

$$\begin{aligned} u(a) - u(b) = u(b) - u(c) &= K_1 \\ = u(\$50{,}000) - u(\$30{,}000) &= 25 \\ 75 - u(\$30{,}000) &= 25 \\ u(\$30{,}000) &= 50. \end{aligned}$$

Three points ($a$, $b$, and $c$) have now been found on the utility function. By similar methods, utility values corresponding to monetary values $d$, $e$, . . . , $j$ also can be derived and plotted to approximate the complete utility function.

Table 1 summarizes the general information on the six case study farms and shows the general form of Bernoullian utility function obtained for each. The specific Bernoullian utility functions for the six case-study farms are shown in Table 2. Two subjects (farms 2 and 4) have constant marginal utility functions, three (farms 1, 3, and 6) have diminishing marginal utility (risk aversion) over the entire range, while one (farm 5) has a range first of diminishing marginal utility followed by a range of increasing marginal utility (risk preference). Table 1 suggests no obvious direct relationship between the form of the utility function and the size or form of ownership of the firm, although the number of observations is admittedly too small to allow conclusions to be drawn.

[5] The use of net farm income as "payoffs" and alternative economic conditions as "states of nature" was designed to provide farmers with a sense of "realism" in responding to the decision games. The farmer was simply asked to respond as realistically as possible as to how he *would* react faced with the particular alternatives. The procedure assumed that the net incomes were "after tax" figures, i.e., that the farmer would retain the full values of the stated net incomes.

[6] The Bernoullian utility function is unique up to a linear transformation; that is, the origin and scale are arbitrary, effectively established by the assignment of utility values $u^*(a)$ and $u^*(b)$. In this respect the Officer-Halter study [16] appears to have been in error in assigning three utility values arbitrarily, thus arbitrarily affecting the *shape* as well as the origin and scale of the utility function. For a comparison between the method used here and that of Officer-Halter, see Lin [13].

Table 1. Data on farm size, organization, and utility functions for the six case study farms

| Type of Information | Farm 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Farm size (irrig. areas) | 2,200 | 2,750 | 3,000 | 26,500 | 7,500 | 8,500 |
| Form of organization | Partnership (two brothers) | Partnership (father-son) | Partnership (father-son) | Corporation | Corporation | Partnership (7 partners) |
| Utility function derived for: | Older brother | Son | Father | Manager | Manager | Manager |
| *Form of utility function:* | | | | | | |
| Bernoullian | Diminishing marg. util. | Constant marg. util. | Diminishing marg. util. | Constant marg. util. | Diminishing-increasing marg. util. | Diminishing marg. util. |
| Lexicographic | Max $E(\pi)$ s.t. $\Pr(\pi \geqslant -\$100{,}000) \geqslant 0.90$ | Min $\Pr(\pi \leqslant -\$150{,}000)$ s.t. $E(\pi) \geqslant \$130{,}000$ | Max $E(\pi)$ s.t. $\Pr(\pi \geqslant -\$200{,}000) \geqslant 0.90$ | Max $E(\pi)$ s.t. $\Pr(\pi \geqslant -\$2{,}500{,}000) \geqslant 0.98$ | Max $E(\pi)$ s.t. $\Pr(\pi \geqslant -\$200{,}000) \geqslant 0.95$ | Max $E(\pi)$ s.t. $\Pr(\pi \geqslant -\$1{,}000{,}000) \geqslant 0.98$ |

## Lexicographic utility

It has been suggested by several authors [6, 8, and 9] that the multiple-goal objective functions of decision makers may best be captured by some form of lexicographic utility. For the farmers interviewed, four general goals were specified as important:[7]

$C =$ family living standard (consumption),
$\Delta NW =$ firm growth goal (change in net worth),
$\pi =$ a net income goal (level of profit),
$s =$ a security, farm survival, or risk aversion goal.

Each farmer was asked to rank these four goals in order of importance and to specify "satisfactory" levels of his first three since, following lexicographic theory, the firm is assumed to maximize (or minimize) the least important (fourth) goal, subject to "satisfactory" levels of the dominant (first three) goals.

While the four goals were specified as "independent," it is clear that three are directly related through the accounting equation $\Delta NW = \pi - C$. Thus, in cases where one of these three goals is the least important in the firm's four-goal structure, the situation simplifies to one in which profit ($\pi$) is maximized subject to the risk restraint ($s$). This point can be illustrated with reference to firm 1, where, in order of importance, "satisfactory" goal levels (indicated by asterisks) are:

$s^* =$ A risk aversion, or farm survival goal. The satisfactory level of $s(s^*)$ states that the probability of obtaining a net income in any single year less than the "disaster" level of —$100,000 must be less than 10 percent; i.e., $s^* = \text{Prob}\ (\pi \geqslant -\$100{,}000) \geqslant 0.90$.
$\pi^* =$ A satisfactory expected net income level $\geqslant$ \$100,000.
$C^* =$ A satisfactory consumption level $\geqslant$ \$20,000.
$\Delta NW =$ Maximization of growth in net worth.

According to this specification, farm 1 seeks to

[7] The goals of these decision-makers are slightly more "business oriented" than the goal orientation of farm families reported in previous studies, which included living standard, farm ownership, leisure-family relationships, and credit-using, risk-taking behavior [14, 17]. Limitation of the particular goals only to "business" objectives may have contributed to the poor predictive power of the lexicographic model.

Table 2. Summary of Bernoullian utility functions derived for each case study farm, using modified Ramsey model

| Subject (farm) | Estimated utility functions[a] | $R^2$ |
|---|---|---|
| 1 | $U = 44.52 + 1.96M - 0.0099M^2$<br>(9.64) (7.98) (−3.83) | 0.98 |
| 2 | $U = 60.05 + 0.85M$<br>(20.50) (15.40) | 0.98 |
| 3 | $U = 55.74 + 1.27M - 0.0031M^2$<br>(18.11) (16.16) (−2.17) | 0.99 |
| 4 | $U = 64.93 + 0.89M$<br>(40.35) (31.15) | 0.99 |
| 5 | $U = -54.01 + 9.67M - 0.19M^2 + 0.0012M^3$<br>(−5.10) (5.60) (−3.31) (2.56) | 0.96 |
| 6 | $U = 70.01 + 1.30M - 0.0064M^2$<br>(10.99) (19.25) (−4.14) | 0.98 |

[a] $U$ = utility value; $M$ = monetary value (measured in \$1,000). Figures in parentheses are $t$-values.

maximize the increase in net worth ($\Delta NW$) subject to satisfactory constraints on farm survival ($s^*$), profit ($\pi^*$), and consumption ($C^*$). However, since maximizing the increase in net worth ($\Delta NW$) with consumption held at level $C^*$ requires maximizing $\pi$ (because of the accounting relation $\Delta NW = \pi - C$), the goal structure reduces to maximizing profit subject to the firm survival goal; i.e., max $E(\pi)$, s.t. Prob ($\pi \geqslant -\$100{,}000) \geqslant 0.90$.

Farms 1, 3, 4, 5, and 6 have goal structures which reduce to similar formulations (see Table 1). Farm 2, however, presents a case in which the survival goal is the least important and must be optimized with respect to satisfactory levels of the other three goals. Using the accounting equation ($\Delta NW = \pi - C$), satisfactory levels of the other three goals imply a minimum expected profit $\geqslant$ \$130,000. Thus the goal structure of farm 2 reduces to one of minimizing the probability of a loss greater than −\$150,000 subject to an expected income $\geqslant$ \$130,000; i.e., min Prob ($\pi \leqslant -\$150{,}000$) s.t. $E(\pi) \geqslant \$130{,}000$.[8]

To close this section, it may be of interest to discuss briefly the problems encountered in deriving utility functions in the field. The authors met with each farmer several times to obtain technical data, required of any farm management study, and to derive his subjective probabilities of crop yields and prices, as well as to estimate his utility function. The latter required two sessions of one to two hours each. In contrast with earlier studies [e.g., 16], this set of decision makers had little difficulty thinking in terms of the probabilities necessary to complete the utility "games." Surprisingly, they seemed to have greater hesitancy and lack of confidence in specifying the "disaster" and "satisfactory" income levels required for the lexicographic formulation. Another practical matter is whether the manager's utility function accurately reflects corporate (Board of Directors) goals (farms 4, 5). Experience with farm corporations indicates that the manager generally has a dominant influence on the sub-set of decisions regarding annual cropping patterns. However, the appropriate method of deriving a corporate utility function for a broader range of decisions seems still to be an open question, including the constraints imposed by lending institutions.

## Tests of Utility and Profit Maximization Hypotheses

Each of the three alternative behavioral hypotheses (Bernoullian utility maximization, lexicographic utility maximization, and profit maximization) can now be used to derive the optimum plan along the "after tax" $E$-$V$ frontier. Figure 3 illustrates the procedure for farm 1. The Bernoullian utility function for farmer 1 implies an indifference map with constant utility curves of the shape shown. Point $B_1$ (cropping plan 8) on the "after tax" $E$-$V$ frontier provides maximum Bernoullian utility, $u = 81$.[9]

The lexicographic utility function specified by

[8] The lexicographic formulations for farms 1, 3, 4, 5, and 6 are similar to the "safety-first" criterion of Telser [20], while farm 2 is more closely related to the "disaster" level criteria proposed by Kataoka [11] and Roy [18].

[9] The utility maximizing plan "after taxes" (point $B_1$, crop plan 8) predicts a more risky cropping system than "before taxes" (point $B_1$, crop plan 3), giving support to the idea that the complex of tax laws may induce more risk-taking behavior.

farmer 1 was to maximize expected income subject to Prob $(\pi \geq -\$100{,}000) \geq 0.90$. The curve at the bottom of Figure 3 shows the income at the lower 10 percent point of the income distribution for each of the "after tax" *E-V* points. Thus, although plans 3 through 12 all respect the "satisfactory" level of the risk constraint, plan 12 (point $L_1$) is optimal because it has the highest expected net income value of this set. (Plan 13 has a higher expected net income value, but violates the risk constraint.)

The profit-maximizing hypothesis in a risk framework is typically specified as one of maximizing expected profit. This objective function effectively ignores risk, implying a linear Bernoullian utility function and indifference curves in the *E-V* space which are linear, parallel vertical lines. Thus, expected profit maximization leads to selection of the point farthest to the right along the *E-V* frontier (point $P_1$ in Figure 3).

### Test 1: Prediction of actual behavior

The components are now available for tests of the explanatory and predictive power of the three alternative behavioral hypotheses. Test 1 compares the ability of the three hypotheses to explain actual behavior (i.e., the actual farm plan in 1972). Obviously, an "actual" farm plan has many dimensions—acreages of various crops, average income, input levels, etc. However, the best single characterization of a farm plan is perhaps its income distribution, i.e., the *E* and *V* associated with the plan (assuming normality, as appears reasonable in our case). Thus, comparisons of predictions with actual plans are made within the *E-V* space.

Figure 4 shows the plans predicted by Bernoullian utility ($B$), lexicographic utility ($L$), and expected profit maximization ($P$) compared with the actual plan ($A$) for each farm. (Disregard the $D_i$ points for the moment.) Visual inspection suggests that Bernoullian utility predicts "best" in three cases (farms 1, 3, and 6), lexicographic utility predicts "best" in two cases (farms 2 and 5), and profit maximization predicts best in none of the cases. (All three hypotheses predict equally poorly for farm 4).

A more rigorous comparison was provided by using the chi-square goodness-of-fit test to determine whether the income distribution from each *predicted* plan differed significantly from the *actual* plan. More precisely, the chi-square value can be used to calculate the probability of obtaining the two different distributions at random when in fact the two have the same mean and variance—the higher the probability level the "closer" is the prediction. The results of this test are shown in Table 3. While the pattern of chi-square values confirms the results of visual inspection, only the predictions for farms 1, 2, 3, and 6 show a non-zero probability that the predicted distribution equals the actual distribution.

While this limited test should be expanded to include more farms and years, it is tentatively concluded that the Bernoullian and lexicographic utility predict actual behavior more accurately than expected profit maximization, with an advantage to the former. Most striking, perhaps is the poor predictive power of the classical behavioral assumption of expected profit maximization—the probability of a "correct" prediction from this assumption was essentially zero in all six cases.

### Test 2: Prediction of "preferred" (direct choice) behavior

A troublesome feature of the above test was the tendency for most of the behavioral hypotheses to "overpredict" actual behavior, i.e., to predict higher risk plans than were actually followed in 1972. The implicit assumption in the test was that the *actual* plan accurately reflected the *true preferences* of the decision-maker. This assumption could have been invalid for a number of reasons. First, because of restrictions of which the authors were unaware, the decision-makers might have been unable in 1972 to adjust their actual plans toward their preferred plans for the long run. Second, the decision-maker might simply have made an error in selecting a plan which he thought matched his preferences. Third, his preferences could have changed. For these reasons, a second test was proposed in which the predictions of utility and profit maximization were compared with the farm plan along the *E-V* frontier *selected directly* by the decision-maker. That is, the decision-maker was shown the *E-V* frontier (suitably presented in discrete tabular form based on the mean and standard deviation of each plan) and asked to select directly that plan he would prefer. The assumption in this case was that the plan *selected directly* by the producer rather than the *actual plan* reflected his true preferences.

Visual inspection of Figure 4 shows a clear verdict in favor of Bernoullian utility ($B$), in

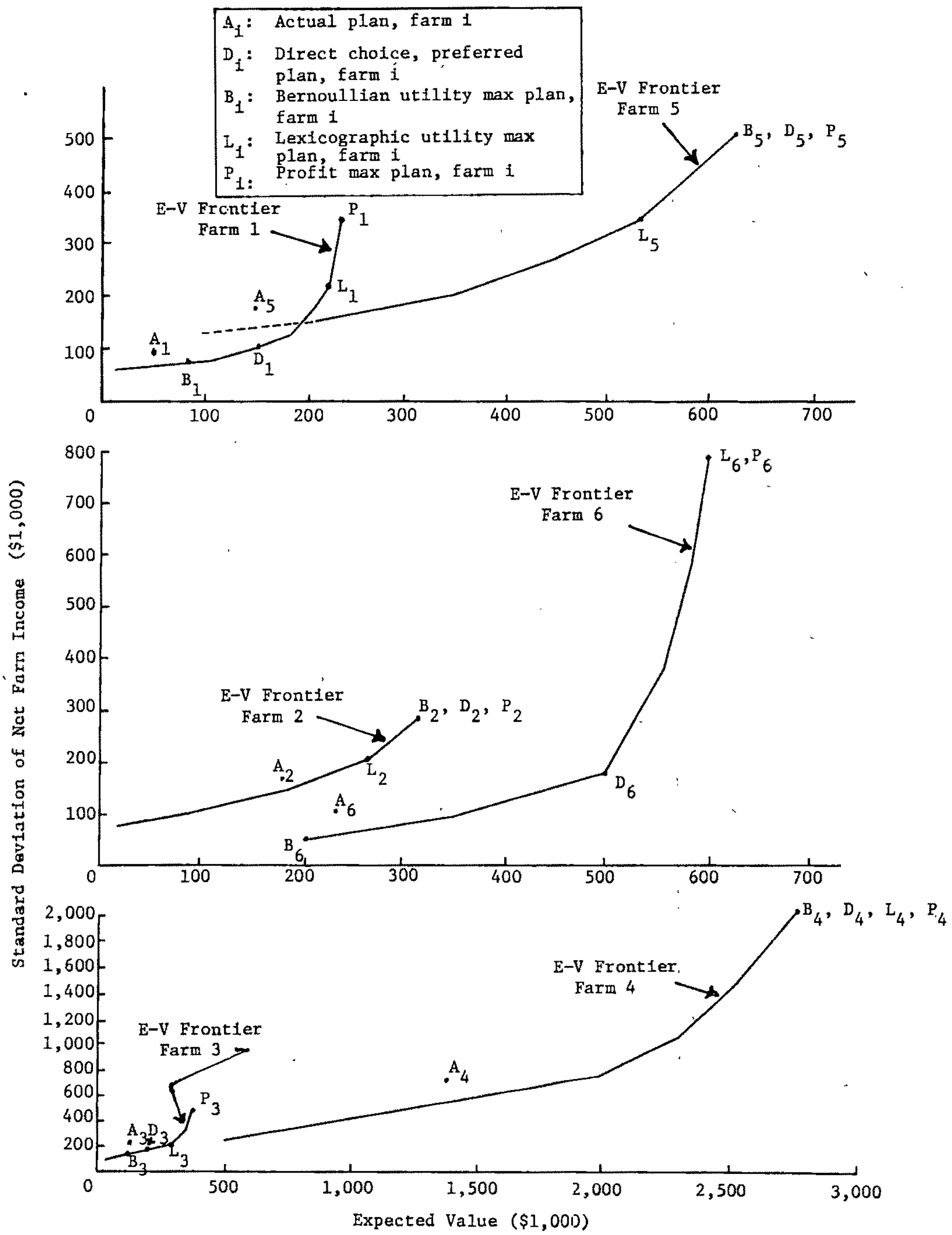


**Figure 4. Comparisons of utility and profit maximizing plans with actual and direct choice of preferred plan, six case study farms**

that it predicts exactly the *direct choice plan* (*D*) in three cases (farms 2, 4, and 5) and appears to predict more closely than the alternative hypotheses in farms 1 and 3 (and possibly in 6). Further, the prediction is qualitatively reasonable in every case. When the *direct choice plan* (*D*) is at the maximum expected income (upper end of the *E-V* frontier), the Bernoullian utility function has constant or increasing marginal utility over the relevant range and correctly predicts this plan (farms 2, 4, and 5). And, when the direct choice is at some intermediate point along the *E-V* frontier, implying risk aversion, the Bernoullian utility function

Table 3. Chi-Square goodness-of-fit test and the estimated probability of income distributions of actual and predicted plans being equal

| | Calculated $\chi^2$ Value[a] | | | Estimated Probability[b] | | |
|---|---|---|---|---|---|---|
| Farm | Bernoullian utility | Lexicographic utility | Profit maximization | Bernoullian utility | Lexicographic utility | Profit maximization |
| 1 | 0.96 | 7.63 | 11.25 | 0.62 | 0.02 | 0.01 |
| 2 | 13.75 | 2.95 | 13.75 | 0.00 | 0.40 | 0.00 |
| 3 | 1.00 | 19.80 | 26.40 | 0.61 | 0.00 | 0.00 |
| 4 | 43.40 | 43.40 | 43.40 | 0.00 | 0.00 | 0.00 |
| 5 | 22.67 | 20.69 | 22.67 | 0.00 | 0.00 | 0.00 |
| 6 | 2.50 | 60.00 | 60.00 | 0.56 | 0.00 | 0.00 |

[a] Underlined values show best predictors of actual behavior on each farm.
[b] Underlined values show the predictor with the highest probability that the actual and predicted plans are equal.

does in fact show diminishing marginal utility and predicts (although not completely accurately) an action with less than maximum expected income (farms 1, 3, and 6).

The more formal chi-square goodness-of-fit test of the alternative behavioral assumptions is provided in Table 4. Again, Bernoullian utility performs more consistently overall than either lexicographic utility or profit maximization. Bernoullian utility predicts *direct choice* behavior as accurately or more accurately than profit maximization in five of six cases. Lexicographic utility performed rather erratically—in comparison with profit maximization it "won" twice, "lost" twice, and "tied" twice. The profit maximization hypothesis predicted correctly three times but with large errors three times. Further, the "correct" predictions were for cases in which the Bernoullian utility function also predicted correctly, thereby providing empirical support for the theoretical argument that expected profit maximization can be treated as a special case (constant marginal utility) or Bernoullian utility.

## Conclusions

The current study supports the conclusion of Officer and Halter [16] that Bernoullian utility maximization explains actual farmer behavior more accurately than profit maximization (cost minimization). Lexicographic utility functions, on the other hand, although apparently related more closely to the actual decision processes of farmers, performed poorly—only slightly better than profit maximization—in predicting actual and planned decisions.

None of the models predicted actual behavior well, with a strong tendency for all models to predict more risky behavior than was in fact observed. Profit maximization was the worst offender in this regard, consistently predicting cropping plans far more risky than those actually followed. This may explain why standard linear programming (LP) results are often disregarded by farmers as "unrealistic" and why aggregation of individual farm LP studies to predict industry behavior (e.g., supply functions) usually have overestimated actual responses. On the basis of

Table 4. Chi-Square goodness-of-fit test and the estimated probability of income distribution of preferred (direct choice) and predicted plans being equal

| | Calculated $\chi^2$ Value[a] | | | Estimated Probability[b] | | |
|---|---|---|---|---|---|---|
| Farm | Bernoullian utility | Lexicographic utility | Profit maximization | Bernoullian utility | Lexicographic utility | Profit maximization |
| 1 | 4.13 | 4.68 | 11.83 | 0.25 | 0.20 | 0.01 |
| 2 | 0.00 | 1.70 | 0.00 | 1.00 | 0.63 | 1.00 |
| 3 | 1.84 | 7.67 | 9.19 | 0.55 | 0.06 | 0.03 |
| 4 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 | 1.00 |
| 5 | 0.00 | 2.28 | 0.00 | 1.00 | 0.89 | 1.00 |
| 6 | 56.00 | 13.75 | 13.75 | 0.00 | 0.00 | 0.00 |

[a] Underlined values show best predictors of actual behavior on each farm.
[b] Underlined values show the predictor with the highest probability that the actual and predicted plans are equal.

these results, it is hypothesized that better predictions of aggregate behavior would result from concentrating on aggregating farms with similar utility functions, even if this meant a sacrifice in the level of detail in the input-output matrix and constraint vector in the standard LP format.

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# A Model of a Bargaining Cooperative*

George W. Ladd

**This paper analyzes behavior of a cooperative of raw material producers. The cooperative sells a production input to producers, provides a "free" service to members, and bargains with processors for raw material price. One analysis assumes the cooperative's objective is maximization of the raw material price received by members. Another assumes the objective is maximization of quantity marketed through the cooperative. The cooperative has three instruments to manipulate to attain its objective. First-order maximization conditions for the two objectives are quite different from each other and from "marginal cost equals marginal revenue" conditions.**

*Key words:* **theory; bargaining; cooperatives.**

Economists have many models of proprietary firms: profit maximizing models; constrained sales maximization models, utility maximization models; models for single-product firms and multi-product firms; models for purely competitive firms, imperfectly competitive firms, and monopolistic firms. Although cooperative firms are important in marketing agricultural products and supplying farm inputs, they are diverse in nature and operation, their objectives differ from those of proprietary firms, and they face some problems that proprietary firms do not face, there are few models of cooperative firms. The lack of well-developed models of cooperatives seriously restricts economists' ability to understand and predict cooperative behavior. The ultimate objective of the work whose initial steps are reported in this paper is development of operational methods of cooperative behavior.

## Problem Situation

In 1962 Helmberger and Hoos ". . . show[ed] that by assuming maximizing behavior on the part of the cooperative enterprise, behavioral relations and positions of equilibrium can be derived through traditional marginal analysis. This, in turn, lays the foundation for the more comprehensive task of adapting theory of the firm, in its entirety, to the cooperative enterprise" [1, p. 281]. They assumed that the cooperative's objective is to maximize the cooperative surplus —excess of revenue over total costs exclusive of payments to members for raw material. In their short-run analysis they assumed a fixed amount of raw material supplied to the cooperative by its members and a fixed price received by the cooperative. Maximizing of surplus then required minimization of total processing cost. They showed that minimization of total processing cost implies equating product price to marginal cost. They discussed two long-run formulations: restricted membership policy and open membership policy. In the first, member supply of raw material is a variable influenced by the cooperative. In the second policy, member supply of raw material is viewed as being outside the cooperative's control.

This paper extends the analysis of Helmberger and Hoos in four ways. (1) Their cooperative's selling price was fixed; here this price is a variable, dependent in part upon the cooperative's actions. (2) They compared two membership policies but did not discuss how to implement them nor how to determine which is superior. This paper derives rules for determining optimum membership and provides instruments for its attainment. (3) Optimality conditions for cooperatives having different objectives are compared here. (4) The only service their cooperative performed for its members was processing members' raw material and selling the final product. A multi-service cooperative is considered here.

A model of a bargaining cooperative is presented here. Many cooperatives marketing fruits, vegetables, and Grade A milk are bargaining cooperatives. Their prime activity is the selling of members' raw products to processors. Various bargaining activities may be involved in this selling function, including face-to-face negotiations with processors with no third parties present;

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preparation and presentation of testimony in the quasi-judicial atmosphere of an administrative hearing on a marketing order; and provision of services to processors and negotiations over the size of the service charge to be paid by processors. The latter represents a cooperative's exercise of "opponent-gain power." The cooperative may also exercise "opponent-pain power" in which it takes actions harmful to processors and ceases these actions only after certain demands are met. (These two types of bargaining power are discussed in Ladd [3; pp. 14–20, 112–113].)

These bargaining activities share one important attribute with nonexcludable public goods. Benefits of nonexcludable public goods are available to everyone; they cannot be limited to one group of people, e.g., to the persons whose taxes provide the public good. The bargaining activities benefit all producers—member and nonmember—because the price paid to nonmembers by processors is strongly affected by the price received by members of the cooperative. For example, some processors are unwilling to pay nonmembers a price lower than the price received by members. The public goods aspect of bargaining creates problems for bargaining cooperatives. Each member has an incentive to become a nonmember, for by doing so he can avoid the cost of supporting the bargaining while continuing to receive the higher price provided by the bargaining. Resulting declines in membership tend to increase the cooperative's cost per unit of member product handled and to reduce the cooperative's bargaining effectiveness by reducing the supply of product under its management. Continued membership thus becomes less attractive to the remaining members.

A cooperative can counter this problem by providing services that resemble excludable public goods: provide attractive services to members without direct charge, but do not provide these services to nonmembers. Examples are the provision of services of a field man who helps members having quality control or pest problems, provision of advice on a feeding or fertilizing program, or the provision of group life insurance to members.

Many bargaining cooperatives also sell production inputs. This activity may also attract members.

## Variables and Equations: General Model

The cooperative considered here provides three services. The first is the sale of an item used as a productive input by members (and nonmembers)—e.g., milking supplies by a dairy cooperative or harvesting crates by a fruit cooperative. This service is assumed to be sold to both member and nonmember producers. The second service is an excludable public good provided only to members. The cooperative does not sell this service to the individual members who use it nor does the cooperative make a direct charge against each member in proportion to his use of this service. The cooperative's total cost of providing this service is met from the cooperative's revenues from sales of the first service and sales of the members' raw product. The third service provided by the cooperative is the bargaining service: bargaining with processors for the price they will pay for the members' raw product.

Let $X_m$ be the quantity of raw product produced by cooperative members, $X_n$ be the quantity produced by nonmembers, and $X_0$ be their total:

$$X_0 = X_m + X_n. \tag{1}$$

The analysis is short-run in the sense that $X_0$ is assumed constant, but $X_m$ and $X_n$ can vary through offsetting changes. This allows supply by members to rise or fall but requires each change in $X_m$ to be offset by a change in $X_n$.[1] It is assumed that all raw material produced by members is delivered to the cooperative and that no raw material produced by nonmembers is delivered to the cooperative. For the analysis here, the most illuminating interpretation of $X_m$ is: $X_m =$ the quantity of raw material that is marketed under the management or control of the cooperative. (A list of all variables and their definitions is presented in the Appendix.)

Let $P_m$ be the price received by members from the cooperative for their raw product and let $P_n$ be the price received by nonmembers for their raw product. Also, let $P_1$ be the price charged by the cooperative for the first service—the item used by member and nonmember producers as a productive input—and let $P_c$ be the price charged for this same input by other firms. Finally, let $S_2$ be the amount of the second service—the excludable public good—provided to members. Theory of the firm states that a firm's supply of a product is related to product and

[1] Two types of offsetting changes are these: (a) A nonmember becomes a member, or vice versa, without changing his level of production. (b) A member sells part of his production facilities to a nonmember, or vice versa, and the new owner's production from the purchased facilities exactly equals the previous owner's production from those facilities.

input prices. Increases in $S_2$ may enable an individual producer to increase his output. Supply of raw product by the average member may be expressed as $Q_m = f(P_1, P_c, P_m, S_2)$. Total supply by all members depends upon supply per member and number of members. Number of members will be affected by the ratio or difference between $P_n$ and $P_m$ and also by $S_2$. Hence total supply by members is expressed as

$$X_m = \phi_2(P_1, P_c, P_m, P_n, S_2). \tag{2}$$

$X_m$ is positively related to $P_m$ and $S_2$ and negatively related to $P_1$, $P_c$, and $P_n$.

Theory of the firm also states that an individual firm's demand for an input is related to input and output prices. Because the first service is sold to both members and nonmembers, demand is assumed to depend upon $P_m$, $P_n$, and $P_1$. It is assumed that a small number of other firms also sell this service to producers, and the price charged by these other firms is $P_c$. Assume that provision of increasing amounts of the second service to members induces members to make a greater proportion of their purchases of the first service from the cooperative. Letting $S_1$ be the quantity of the first service sold by the cooperative, the demand function for this service is

$$S_1 = \phi_3(P_1, P_c, P_m, P_n, S_2). \tag{3}$$

$S_1$ is positively related to $P_m$, $P_n$, $P_c$, and $S_2$ and is negatively related to $P_1$.

Let $P_0$ be the price received by the cooperative from processors for raw material produced by members, and let $S_3$ be the amount of the bargaining service performed by the cooperative. The number of processors is assumed to be small and each processor is assumed to face a downward sloping demand curve for his output. Therefore $P_0$ and $X_0$ are expected to be negatively related. Through its bargaining activities the cooperative can influence the price paid by processors. Therefore $P_0$ and $S_3$ are expected to be positively related. It is expected that the cooperative's bargaining power is positively correlated with the fraction of total supply produced by members: $X_m/X_0$. Therefore the determination of $P_0$ can be described by

$$P_0 = \phi_4(X_0, X_m/X_0, S_3). \tag{4}$$

Total return to members is $P_mX_m$, and this equals total cooperative revenue $(P_0X_m + P_1S_1)$ minus total operating costs:

$$P_mX_m = P_0X_m + P_1S_1 - C(S_1, S_2, S_3, X_m).$$

$C(S_1, S_2, S_3, X_m)$ is the cooperative's total cost function showing total cost to depend upon total supply under the management of the cooperative and the amount of each service performed.[2] Member price is, therefore,

$$P_m = P_0 + [P_1S_1 - C(S_1, S_2, S_3, X_m)]/X_m. \tag{5}$$

Price to nonmembers is determined from

$$P_n = P_0 - D \tag{6}$$

where $D$ is a parameter beyond the control of the cooperative. It includes, e.g., the cost to proprietary firms of performing services in procuring products from nonmembers: services provided by the cooperative to firms procuring raw material from members.

Equation (4) and variable $P_0$ can be eliminated from the system of equations by substituting the right-hand side of (4) into (5) and (6). This yields

$$P_m = \phi_4(X_0, X_m/X_0, S_3) + [P_1S_1 - C(S_1, S_2, S_3, X_m)]/X_m$$

$$P_n = \phi_4(X_0, X_m/X_0, S_3) - D.$$

These can be expressed as

$$P_m = G_1(X_0, P_1, S_1, S_2, S_3, X_m) \tag{7.1}$$

$$P_n = G_2(X_0, X_m, S_3, D). \tag{7.2}$$

Equations (2) and (3) can be rewritten as

$$X_m = G_3(P_1, P_c, P_m, P_n, S_2) \tag{7.3}$$

$$S_1 = G_4(P_1, P_c, P_m, P_n, S_2). \tag{7.4}$$

Equation (1) can be rewritten as

$$X_n = X_0 - X_m. \tag{7.5}$$

Equations (7.1) through (7.5) form a system of five equations in the five dependent variables ($P_m$, $P_n$, $X_m$, $S_1$, and $X_n$) and six independent variables ($P_1$, $S_2$, $S_3$, $X_0$, $D$, and $P_c$). The values of $P_1$, $S_2$, and $S_3$ will be determined from maximization conditions. The values of these three variables and of $X_0$, $D$, and $P_c$ can then be used to determine $P_m$, $P_n$, $X_m$, $S_1$, and $X_n$.

The signs of most of the partial derivatives are

[2] One reviewer questioned the inclusion of $X_m$ along with $S_1$, $S_2$, and $S_3$ in this function because it is not clear that total costs would change if members alter their output levels but the same quantities of services are provided by the cooperative. One way to justify inclusion of $X_m$ is to assume that the cooperative performs still a fourth service, and the quantity of this service is in direct proportion to $X_m$. See footnote 3.

clear from the preceding discussion. But some merit special attention. Because some sets of variables appear in more than one equation, it is necessary to identify the equation for which partial derivatives are evaluated. Thus, for example, $(\partial S_1/\partial P_m)_4$ denotes the partial derivative of $S_1$ with respect to $P_m$ in equation (7.4); $(\partial P_m/\partial P_1)_1$ identifies the partial derivative of $P_m$ with respect to $P_1$ in (7.1); $(\partial X_m/\partial P_m)_3$ identifies the partial derivative of $X_m$ with respect to $P_m$ in (7.3). Note that, because two equations are involved, one cannot "cancel" in products of partial derivatives. That is, e.g., one cannot assume $(\partial P_m/\partial S_1)_1\,(\partial S_1/\partial P_m)_4 = 1$. It may happen in a particular numerical application that the product of these two partial derivatives would equal one; but one cannot assume this equality *a priori*.

In evaluating (7.1), let $R_1 = P_1 S_1$

$$(8.1) \qquad (\partial P_m/\partial X_0)_1 < 0$$

$$(8.2) \qquad (\partial P_m/\partial P_1)_1 = S_1/X_m > 0$$

$$(8.3) \qquad (\partial P_m/\partial S_1)_1 = (\partial R_1/\partial S_1 - \partial C/\partial S_1)/X_m \gtreqless 0$$

$$(8.4) \qquad (\partial P_m/\partial S_2)_1 = -(\partial C/\partial S_2)/X_m < 0.$$

In evaluating the next partial derivatives, it will be convenient to introduce the auxiliary variable $\rho = X_m/X_0$ and to use equations (1), (4), (5), and (6). The absence of a subscript on a partial derivative will indicate that it is taken from one of these equations. The context will make clear which equation the partial derivative is taken from.

$$(8.5) \qquad (\partial P_m/\partial S_3)_1 = \partial P_0/\partial S_3 - (\partial C/\partial S_3)/X_m \gtreqless 0.$$

Note that $(\partial P_m/\partial X_m)_1 = \partial P_0/\partial X_m + \partial(R_1/X_m - C/X_m)/\partial X_m$ and $\partial P_0/\partial X_m = (\partial P_0/\partial X_0)(\partial X_0/\partial X_m) + (\partial P_0/\partial \rho)(\partial \rho/\partial X_m)$. Therefore,

$$(8.6) \qquad (\partial P_m/\partial X_m)_1 = \partial P_0/\partial X_0 + (\partial P_0/\partial \rho)(X_n/X_0^2) + (C - R_1)/X_m^2 - (\partial C/\partial X_m)/X_m \gtreqless 0.$$

The first term on the right hand side of (8.6) is negative, the second is positive, the third is expected to be positive, and the fourth is positive.[3]

Evaluating (7.2) yields[4]

$$(9.1) \qquad (\partial P_n/\partial X_m)_2 = \partial P_0/\partial X_0 + (\partial P_0/\partial \rho)(X_n/X_0^2) \gtreqless 0$$

$$(9.2) \qquad (\partial P_n/\partial S_3)_2 = \partial P_0/\partial S_3 > 0.$$

Following Helmberger and Hoos [1], it is initially assumed that the cooperative's objective is to maximize $P_m$. Surveys of dairy bargaining cooperatives show this to be an important objective of these cooperatives [2, 4]. The instruments available to the cooperative for accomplishing this objective are $P_1$, $S_2$, and $S_3$. The cooperative's problem is to determine the price that should be charged for the first service and the quantities of the second and third services that should be provided to maximize $P_m$. Previously cited studies of dairy bargaining cooperatives show that some important objectives relate to volume of raw material supplied by members [2, 4]. Therefore a cooperative whose objective is to maximize $X_m$ will also be considered.

The assumptions listed in (8.1) through (8.6), (9.1), and (9.2) and the assumptions presented in the discussions of specific equations constitute the General Model that is the subject of most of the analysis. Some other situations are discussed briefly below.

## Counter Models

Each Counter Model contradicts an assumption of the General Model.

I. Suppose that the amount of raw material marketed under the control of the cooperative is not affected by the price of the first service. Then $(\partial X_m/\partial P_1)_3 = (\partial X_m/\partial P_c)_3 = 0$.

II. Suppose that provision of the second service neither encourages sales of the first service nor increases the supply of raw product marketed under the cooperative's management. Then $(\partial S_1/\partial S_2)_4 = (\partial X_m/\partial S_2)_3 = 0$.

III. Suppose $\partial P_0/\partial S_3 = 0$. That is, the bargaining service fails to influence the price paid to the cooperative by processors for the members' raw product.[5]

[3] If the cooperative's cost function does not contain $X_m$, it is still true that $(\partial P_m/\partial X_m)_1 \gtreqless 0$. See footnote 2. Thus the qualitative results to be presented in this paper are unaffected if $X_m$ is eliminated from the cost function.

[4] Comparison of (8.5) and (9.2) shows that $(\partial P_m/\partial S_3)_1 < (\partial P_n/\partial S_3)_2$. This emphasizes the point, made earlier, that bargaining is a public good. Not only do nonmembers benefit from the bargaining activity, but, because they do not help to finance the activity, they benefit from it more than do members in the sense that increasing this activity increases nonmember price more than it increases member price.

[5] A fourth counter model which could be considered is one in which the first service is sold only to members and the demand for this productive input is, therefore, assumed to be independent of the price received by nonmembers. As can be seen by setting $(\partial S_1/\partial P_n)_4 = 0$

## Mathematical Procedure

The five equations (7.1), (7.2), (7.3), (7.4), and (7.5) contain five dependent variables—$P_m$, $P_n$, $X_m$, $S_1$, and $X_n$—and six independent variables—$S_2$, $S_3$, $X_0$, $P_1$, $D$, and $P_c$. If the system were linear in the dependent variables, it would be a simple matter to use matrix operations to solve for the dependent variables as functions of the independent variables. The resulting reduced form of the system could be used to determine optimality conditions, i.e., to determine the values of $P_1$, $S_2$, and $S_3$ that maximize $P_m$ or $X_m$. The system, however, is not linear in the dependent variables. The derivation of (7.1) shows that the right-hand side of (7.1) contains $X_m$ in both the numerator and the denominator. Hence (7.1) is a non-linear function of $X_m$. As is well known, any equation can be "linearized" by taking its total differentials, e.g., if $Y=f(X_1,X_2)$, then $dY=(\partial f/\partial X_1)dX_1 + (\partial f/\partial X_2)dX_2$ is linear in $dY$, $dX_1$, and $dX_2$. If (7.1) through (7.5) are linearized by determining total differentials, the resulting differentials can be used to determine optimality conditions.

Totally differentiating (7.1) yields

$$(10.1)\quad dP_m = (\partial P_m/\partial X_m)_1 dX_m + (\partial P_m/\partial S_1)_1 dS_1 + (\partial P_m/\partial S_2)_1 dS_2 + (\partial P_m/\partial S_3)_1 dS_3 + (\partial P_m/\partial X_0)_1 dX_0 + (\partial P_m/\partial P_1)_1 dP_1.$$

Total differentials of (7.2), (7.3), (7.4), and (7.5) may be similarly determined. The total differentials, and operations with them, can be conveniently expressed by using the following vector-matrix notation. Define

$$J=\begin{pmatrix} 1 & 0 & -(\partial P_m/\partial X_m)_1 & -(\partial P_m/\partial S_1)_1 & 0 \\ 0 & 1 & -(\partial P_n/\partial X_m)_2 & 0 & 0 \\ -(\partial X_m/\partial P_m)_3 & -(\partial X_m/\partial P_n)_3 & 1 & 0 & 0 \\ -(\partial S_1/\partial P_m)_4 & -(\partial S_1/\partial P_n)_4 & 0 & 1 & 0 \\ 0 & 0 & -(\partial X_n/\partial X_m)_5 & 0 & 1 \end{pmatrix}$$

$$dY=(dP_m\ dP_n\ dX_m\ dS_1\ dX_n)'$$

$$K_1=\begin{pmatrix} (\partial P_m/\partial S_2)_1 \\ 0 \\ (\partial X_m/\partial S_2)_3 \\ (\partial S_1/\partial S_2)_4 \\ 0 \end{pmatrix},\qquad K_2=\begin{pmatrix} (\partial P_m/\partial S_3)_1 \\ (\partial P_n/\partial S_3)_2 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

$$K_3=\begin{pmatrix} (\partial P_m/\partial X_0)_1 \\ (\partial P_n/\partial X_0)_2 \\ 0 \\ 0 \\ (\partial X_n/\partial X_0)_5 \end{pmatrix},\qquad K_4=\begin{pmatrix} (\partial P_m/\partial P_1)_1 \\ 0 \\ (\partial X_m/\partial P_1)_3 \\ (\partial S_1/\partial P_1)_4 \\ 0 \end{pmatrix}$$

$$K_5=\begin{pmatrix} 0 \\ (\partial P_n/\partial D)_2 \\ 0 \\ 0 \\ 0 \end{pmatrix},\qquad K_6=\begin{pmatrix} 0 \\ 0 \\ (\partial X_m/\partial P_c)_3 \\ (\partial S_1/\partial P_c)_4 \\ 0 \end{pmatrix}$$

$$K=(K_1\ K_2\ K_3\ K_4\ K_5\ K_6)$$

$$dZ=(dS_2\ dS_3\ dX_0\ dP_1\ dD\ dP_c)'.$$

The total differentials of (7.1) through (7.5) can now be compactly expressed as

$$(11)\qquad JdY=KdZ.$$

It is assumed that $J$ is nonsingular, that is, Det $J\neq 0$ (Det $J$ denotes determinant of matrix $J$).

Setting all elements of $dZ$ equal to zero except $dP_1$, and dividing (11) by $dP_1$ yields $J\partial Y/\partial P_1 = K_4$, from which is obtained

in the first-order equilibrium conditions presented later, however, this assumption has little effect on the qualitative argument and conclusions of this paper.

$$\begin{pmatrix} \partial P_m/\partial P_1 \\ \partial P_n/\partial P_1 \\ \partial X_m/\partial P_1 \\ \partial S_1/\partial P_1 \\ \partial X_n/\partial P_1 \end{pmatrix} = J^{-1}K_4.$$

Applying Cramer's rule yields

$$\partial P_m/\partial P_1 = \text{Det } J_{P1}/\text{Det } J \tag{12}$$

$$\partial X_m/\partial P_1 = \text{Det } J_{X1}/\text{Det } J \tag{13}$$

where $J_{P1}$ is obtained from $J$ by replacing the first column of $J$ by $K_4$, and $J_{X1}$ is obtained from $J$ by replacing the third column of $J$ by $K_4$.

Setting all elements of $dZ$ equal to zero except $dS_2$ and dividing (11) by $dS_2$ yields $\partial Y/\partial S_2 = J^{-1}K_1$. From Cramer's rule,

$$\partial P_m/\partial S_2 = \text{Det } J_{P2}/\text{Det } J \tag{14}$$

$$\partial X_m/\partial S_2 = \text{Det } J_{X2}/\text{Det } J \tag{15}$$

where $J_{P2}$ is obtained from $J$ by replacing the first column of $J$ by $K_1$, and $J_{X2}$ is obtained from $J$ by replacing the third column by $K_1$.

Setting all elements of $dZ$ equal to zero except $dS_3$ and dividing both sides of (11) by $dS_3$ yields $\partial Y/\partial S_3 = J^{-1}K_2$. By Cramer's rule,

$$\partial P_m/\partial S_3 = \text{Det } J_{P3}/\text{Det } J \tag{16}$$

$$\partial X_m/\partial S_3 = \text{Det } J_{X3}/\text{Det } J. \tag{17}$$

Here $J_{P3}$ is obtained from $J$ by replacing the first column of $J$ by $K_2$, and $J_{X3}$ is obtained from $J$ by replacing the third column by $K_2$.[6]

The first-order conditions for maximization of member price are determined by setting (12), (14), and (16) equal to zero. Det $J$ appears in the denominator of each of these. Because it is assumed that Det $J \neq 0$, the first-order conditions are satisfied if and only if Det $J_{P1} = 0$, Det $J_{P2} = 0$, and Det $J_{P3} = 0$. The first-order conditions for maximization of volume under the management of the cooperative are determined by setting (13), (15), and (17) equal to zero. Again, these are zero if and only if Det $J_{X1} = 0$, Det $J_{X2} = 0$, and Det $J_{X3} = 0$.

## Maximization of Member Price

### General Model

The first-order condition for maximization of $P_m$ with respect to $P_1$ is obtained from the expression Det $J_{P1} = 0$.

Evaluation of Det $J_{P1} = 0$ yields

$$\begin{aligned} (18)\quad & (\partial P_m/\partial S_1)_1 \\ & [1 - (\partial P_n/\partial X_m)_2(\partial X_m/\partial P_n)_3](\partial S_1/\partial P_1)_4 \\ & + (\partial P_m/\partial S_1)_1(\partial S_1/\partial P_n)_4 \\ & (\partial P_n/\partial X_m)_2(\partial X_m/\partial P_1)_3 \\ & + (\partial P_m/\partial P_1)_1 \\ & [1 - (\partial P_n/\partial X_m)_2(\partial X_m/\partial P_n)_3] \\ & + (\partial P_m/\partial X_m)_1(\partial X_m/\partial P_1)_3 = 0. \end{aligned}$$

Using (8.3) to replace $(\partial P_m/\partial S_1)_1$ and manipulating (18) yields

$$\begin{aligned} (19)\quad & \partial C/\partial S_1 - \partial R_1/\partial S_1 \\ & = X_m[A_{P1}(\partial P_m/\partial P_1)_1 \\ & + (\partial P_m/\partial X_m)_1(\partial X_m/\partial P_1)_3]/\alpha_{P1} \end{aligned}$$

where

$$\begin{aligned} \alpha_{P1} = {} & A_{P1}(\partial S_1/\partial P_1)_4 \\ & + (\partial S_1/\partial P_n)_4(\partial P_n/\partial X_m)_2(\partial X_m/\partial P_1)_3 \end{aligned}$$

$$A_{P1} = 1 - (\partial P_n/\partial X_m)_2(\partial X_m/\partial P_n)_3.$$

It follows from the assumptions on signs of the partial derivatives that both the numerator and the denominator of (19) may be positive or negative. Thus (19) shows that an efficient $P_m$ maximizing cooperative in general does *not* operate at a point at which marginal revenue from the sale of the first service equals its marginal cost of providing this service.

The introduction of a notational change may help to clarify the economic interpretation of (19). Read from right to left the second product (involving three derivatives) in $\alpha_{P1}$. Through equation (7.3), variation in $P_1$ affects $X_m$. The magnitude of the effect is $(\partial X_m/\partial P_1)_3$. The resulting variation in $X_m$ affects $P_n$ through (7.2). The magnitude of the effect is $(\partial P_n/\partial X_m)_2$. Finally, the resulting variation in $P_n$ affects $S_1$ through (7.4). The size of the effect equals $(\partial S_1/\partial P_n)_4$. Thus this product measures the size of the indirect effect—through (7.4), (7.2), and (7.3)—of a variation in $P_1$ on $S_1$. Denote this product by $DS_1(4, 2, 3)/DP_1$. Now $(\partial S_1/\partial P_1)_4$ measures the direct effect of variation in $P_1$ on $S_1$. This can be expressed as $DS_1(1)/DP_1$. In determining $\alpha_{P1}$ this direct effect is "adjusted" by being multiplied by $A_{P1}$. Express $A_{P1}DS_1(1)/DP_1$ as $DS_1(A1)/DP_1$ to represent the adjusted direct effect of $P_1$ on $S_1$. Express the sum of $DS_1(A1)/DP_1 + DS_1(4, 2, 3)/DP_1$ as $DS_1(A1 + 4, 2, 3)/DP_1$. This term represents the sum of the adjusted direct effect and of the indirect effect of $P_1$ on $S_1$; it might be called the total adjusted effect of $P_1$ on $S_1$.

The product $(\partial P_m/\partial X_m)_1(\partial X_m/\partial P_1)_3$ in the

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[6] The procedure used here is equivalent to using implicit function theory and Jacobian determinants, two covered in any advanced calculus book.

numerator of (19) measures the indirect effect of variation in $P_1$ on $P_m$ arising from the intervening effects of $P_1$ on $X_m$ and $X_m$ on $P_m$. Write this as $DP_m(1, 3)/DP_1$ and express the entire bracketed term as $DP_m(A1 + 1, 3)/DP_1$. This term represents the total adjusted effect of $P_1$ on $P_m$. The numerator represents the total adjusted effect of variation in $P_1$ on $P_mX_m$ (member revenue) with $X_m$ fixed, i.e., it is the total adjusted effect of variation in $P_1$ on member returns from a fixed volume of raw product.

Equation (19) can now be written as

$$(20)\quad \partial C/\partial S_1 - \partial R_1/\partial S_1 = [X_mDP_m(A1 + 1, 3)/DP_1]/[DS_1(A1 + 4, 2, 3)/DP_1]$$

and can be interpreted as: The $P_m$ maximizing cooperative should set $P_1$ at a level at which the excess of the marginal cost over the marginal revenue of the first service equals the ratio of the total adjusted effect of variation in $P_1$ on $P_mX_m$ ($X_m$ constant) to the total adjusted effect of $P_1$ on $S_1$.

Manipulation of Det $J_{P2} = 0$ and use of (8.4) shows that the optimum level of $S_2$ satisfies

$$(21)\quad \partial C/\partial S_2 = X_m[DP_m(1, 4, 2, 3 + 1, 3 + A1, 4)/DS_2]/A_{P1}$$

where

$$(22)\quad DP_m(1, 4, 2, 3 + 1, 3 + A1, 4)/DS_2 = (\partial P_m/\partial S_1)_1(\partial S_1/\partial P_n)_4(\partial P_n/\partial X_m)_2(\partial X_m/\partial S_2)_3 + (\partial P_m/\partial X_m)_1(\partial X_m/\partial S_2)_3 + A_{P1}(\partial P_m/\partial S_1)_1(\partial S_1/\partial S_2)_4.$$

Because the second service is not sold, it has no direct effect on the revenue of either the cooperative or its members. It does, however, have indirect effects on member revenue, and these indirect effects are represented in (21). The bracketed term in the numerator of (21) measures the sum of two indirect effects and of an adjusted indirect effect of $S_2$ on $P_m$. One indirect effect is exerted through equations (7.1), (7.4), (7.2), and (7.3), another through (7.1) and (7.3), and the adjusted indirect effect through (7.1) and (7.4). Equation (21) can be interpreted as saying: If the cooperative is maximizing $P_m$, the marginal cost of the second service equals the total adjusted contribution of this service to total member revenue from the sale of a fixed volume of raw material, divided by the adjustment factor $A_{P1}$. Marginal cost to the cooperative equals total members' adjusted indirect marginal revenue arising from the second service.

The term $(\partial P_m/\partial S_1)_1$ appears in (21). Using equation (8.3) shows that, in equilibrium, the marginal cost of the second service is related to marginal revenue and marginal cost of the first service.

The first two products in (22) can also be expressed as

$$(23)\quad (DP_m(1, 4, 2 + 1)/DX_m)(\partial X_m/\partial S_2)_3 = (DP_m/DX_m)(\partial X_m/\partial S_2)_3.$$

Now $DP_m/DX_m$ is the sum of two effects of $X_m$ on $P_m$—one indirect and one direct. This term may be positive, negative, or zero. If $[DP_m/DX_m]/A_{P1} > 0$, equation (22) shows that, *ceteris paribus*, increasing the value of $(\partial X_m/\partial S_2)_3$ serves to increase the equilibrium value of $\partial C/\partial S_2$. If $[DP_m/DX_m]A_{P1} > 0$ and if the quantity of raw material marketed under the control of the cooperative is highly responsive to $S_2$, then the cooperative should perform the second service at a level at which marginal cost of this service is relatively high. Assuming a U-shaped marginal cost curve, this means that the equilibrium level of output of the second service is high if $[DP_m/DX_m]/A_{P1} > 0$ and if the volume under the control of the cooperative is highly responsive to variation in $S_2$.

Manipulation of Det $J_{P3} = 0$ and use of (8.5) shows that the optimum level of $S_3$ satisfies

$$(24)\quad \partial C/\partial S_3 = X_m(\partial P_0/\partial S_3) + X_m[DP_m(1, 4, 2 + 1, 3, 2)/DS_3]/A_{P1}$$

where

$$DP_m(1, 4, 2 + 1, 3, 2)/DS_3 = (\partial P_m/\partial S_1)_1(\partial S_1/\partial P_n)_4(\partial P_n/\partial S_3)_2 + (\partial P_m/\partial X_m)_1(\partial X_m/\partial P_n)_3(\partial P_n/\partial S_3)_2.$$

$X_m(\partial P_0/\partial S_3)$ measures the marginal contribution of the bargaining service to the cooperative's revenue from the sale of a fixed volume of member product. $X_mDP_m(1, 4, 2 + 1, 3, 2)/DS_3$ measures the total of the indirect marginal contributions of the bargaining service to member revenue. Equation (24) states: In equilibrium the cooperative should provide service three at a level at which the marginal cost of service three equals the sum of (a) the marginal contribution of service three to cooperative revenue and (b) the adjusted marginal contribution of service three to members' revenue. $DP_m(1, 4, 2 + 1, 3, 2)/DS_3$ may be positive, zero, or negative. In equilibrium, therefore, the cooperative's marginal cost of service three may be greater than, equal to, or less than the marginal contri-

bution of service three to the cooperative's revenue from sale of raw product.

It was previously pointed out that (21) shows that in equilibrium the marginal cost of the second service is related to the marginal revenue and marginal cost of the first service. Equation (24) shows that equilibrium levels of marginal revenue and marginal cost of the first service are also related to the equilibrium level of marginal cost of the third service.

The nature of the first-order conditions in (19), (21), and (24) support the earlier thesis that additional study of theory of cooperative behavior is needed. These conditions are dramatically different from the common "marginal revenue equals marginal cost" rule for profit maximization; they make it abundantly clear that one cannot draw upon the theory of profit-maximizing firms to obtain understanding of cooperative behavior.

### Counter Models

Although it is not possible in the General Model to determine the sign of the right-hand side of (19) from prior information, it is possible to do so in Counter Model I. In this model $(\partial X_m/\partial P_1)_3 = 0$. Thus (19) becomes

$$\partial C/\partial S_1 - \partial R_1/\partial S_1 = X_m(\partial P_m/\partial P_1)_1/(\partial S_1/\partial P_1)_4 < 0.$$

In this Counter Model (and in some situations consistent with the assumptions of the General Model) the cooperative should provide the first service at a volume at which marginal revenue exceeds marginal cost. If the average cost curve is U-shaped or if it continues to decline with increasing volume, the cooperative should operate at a *smaller output* of service one than the output that would equate marginal revenue and marginal cost. This result can be placed in a somewhat more familiar context. From the derivation of (7.1) it is seen that $P_m$ is related to the excess of revenue over total cost *per unit of product*. Consider a single-product proprietary firm that desires to maximize the excess of *average* revenue (i.e., price) over *average* cost. If the firm is making positive profits, this excess is maximized at a point at which marginal revenue exceeds marginal cost. Because the price returned to each cooperative member depends upon the excess of $R_1$ over $C$ per unit of $X_m$, the cooperative should not behave like a profit-maximizing proprietary firm in providing service one, but rather more like a proprietary firm wishing to maximize the margin of price over average cost.

In Counter Model II, $(\partial X_m/\partial S_2)_3 = (\partial S_1/\partial S_2)_4 = 0$. Equation (22) says that in this case $\partial C/\partial S_2 = 0$ in equilibrium. A strict interpretation is: If the second service does not influence the quantity of raw material under the control of the cooperative or affect sales of the first service, then the cooperative should operate the second service at a level at which its marginal cost is zero.

If (9.2) is used to replace $(\partial P_n/\partial S_3)_2$ in (24) by $(\partial P_0/\partial S_3)$, equation (24) says: In Counter Model III, $\partial C/\partial S_3 = 0$ in equilibrium. A strict interpretation is: If the bargaining service has no effect on price paid to the cooperative for its members' raw material, then the cooperative should perform the bargaining service at a level at which its marginal cost is zero.

These odd results—$\partial C/\partial S_2 = 0$ and $\partial C/\partial S_3 = 0$—can be attributed to a mathematical inadequacy. The model does not contain any nonnegativity restrictions. Intuition leads one to expect that imposition of the requirements $S_2 \geqslant 0$ and $S_3 \geqslant 0$ would lead to the equilibrium conditions: (a) if $(\partial X_m/\partial S_2)_3 = (\partial S_1/\partial S_2)_4 = 0$, then $S_2 = 0$; (b) if $(\partial P_0/\partial S_3) = 0$, then $S_3 = 0$. These conditions make economic sense. If service two does not increase the quantity of raw material under the cooperative's management or stimulate sales of the first service, it is not accomplishing its purposes; hence it should be discontinued. If the bargaining service does not improve price, it is not accomplishing its service; hence it should be discontinued.

## Maximization of Supply under Cooperative Management

### General Model

This section briefly summarizes results obtained by assuming that the cooperative's objective is to maximize $X_m$. These results are obtained by evaluating Det $J_{X1} = 0$, Det $J_{X2} = 0$, and Det $J_{X3} = 0$. Results in this section are harder to interpret verbally than the results in the preceding section.

Manipulating Det $J_{X1} = 0$ and using (8.3) yields

$$(25) \quad \partial C/\partial S_1 - \partial R_1/\partial S_1 = X_m[DX_m(3+3,1)/DP_1]/\alpha_{X1}$$

where

$$DX_m(3+3,1)/DP_1 = (\partial X_m/\partial P_1)_3 + (\partial X_m/\partial P_m)_3(\partial P_m/\partial P_1)_1$$

$$\alpha_{X1} = (\partial X_m/\partial P_m)_3(\partial S_1/\partial P_1)_4 - (\partial X_m/\partial P_1)_3(\partial S_1/\partial P_m)_4.$$

Both the numerator and the denominator of (25) may be positive or negative. Thus, in general, neither the efficient $P_m$ maximizer nor the efficient $X_m$ maximizer equates marginal cost and marginal revenue of the first service, but it is not possible to tell from *a priori* considerations whether marginal cost or marginal revenue should be larger.

Manipulation of Det $J_{X2} = 0$ and use of (8.4) yields

$$(26) \quad \partial C/\partial S_2 = X_m[DX_m(A3 + 3, 1, 4)/DS_2]/(\partial X_m/\partial P_m)_3$$

where

$$DX_m(A3 + 3, 1, 4)/DS_2 = [1 - (\partial P_m/\partial S_1)_1(\partial S_1/\partial P_m)_4](\partial X_m/\partial S_2)_3 + (\partial X_m/\partial P_m)_3(\partial P_m/\partial S_1)_1(\partial S_1/\partial S_2)_4.$$

Using (8.3) in (26) shows that the equilibrium level of marginal cost of the second service is related to the equilibrium levels of marginal cost and marginal revenue of the first service.

Manipulation of Det $J_{X3} = 0$ and use of (8.5) yields

$$(27) \quad \partial C/\partial S_3 = X_m(\partial P_0/\partial S_3) + X_m[DX_m(A3, 2 + 3, 1, 4, 2)/DS_3]/(\partial X_m/\partial P_m)_3$$

where

$$DX_m(A3, 2 + 3, 1, 4, 2)/DS_3 = [1 - (\partial P_m/\partial S_1)_1(\partial S_1/\partial P_m)_4](\partial X_m/\partial P_n)_3(\partial P_n/\partial S_3)_2 + (\partial X_m/\partial P_m)_3(\partial P_m/\partial S_1)_1(\partial S_1/\partial P_n)_4(\partial P_n/\partial S_3)_2.$$

Substitution of (8.3) into (27) shows that the equilibrium level of marginal cost of the third service is related to equilibrium levels of marginal cost and marginal revenue of the first service.

## Counter Models

In Counter Model I, (25) yields $\partial C/\partial S_1 - \partial R_1/\partial S_1 < 0$ in equilibrium. In Counter Models II and III, (26) and (27) yield $\partial C/\partial S_2 = 0$ and $\partial C/\partial S_3 = 0$. The previous discussion of Counter Models also applies here.

## Second-Order Conditions

Let $H_P$ be the Hessian matrix of second derivatives of $P_m$ with respect to the three instruments: $P_1$, $S_2$, and $S_3$. And let $H_X$ be the Hessian matrix of second derivatives of $X_m$ with respect to the instruments. Each element of these Hessians is the derivative of the ratio of two 5 by 5 determinants. For example, one element of $H_P$ is

$$\partial(\text{Det } J_{P1}/\text{Det } J)/\partial S_2.$$

It is not possible from *a priori* information to determine the signs of Det $J$ and Det $J_{P1}$; nor is it possible to determine from *a priori* information the sign of the derivative of their ratio.

In interpreting the first-order conditions in this paper, it has been assumed that $H_P$ and $H_X$ are negative semi-definite. Under this assumption, these first-order conditions yield maxima of $P_m$ and of $X_m$.

Being unable to evaluate the elements of $H_P$ and $H_X$ makes it impossible to determine how a cooperative's equilibrium position is affected by variations in the parameters—$X_0$, $D$, and $P_c$.

## Extensions

Both models presented here probably oversimplify the bargaining cooperatives' objective function. Studies cited earlier [2, 4] indicate that cooperatives include both $X_m$ and $P_m$ in their objectives. First-order conditions for a utility-maximizing cooperative whose utility depends upon both $P_m$ and $X_m$ [the cooperative maximizes $U(P_m, X_m)$] are complicated functions of the two sets of first-order conditions derived in this paper. They are not, however, so complicated that they defy quantification. When economists have the information necessary to evaluate the first-order conditions presented here and know (or are willing to assume) something of $\partial U/\partial P_m$ and $\partial U/\partial X_m$, they will be able to quantify the first-order conditions for a maximizer of $U(P_m, X_m)$.

A desirable extension of the present model would add a fourth service: one that is sold only to members and has an effect on $X_m$. The reason for not including such a service in the present model is that adding such a service would add one equation to the model: members' demand for this service. Then the Jacobian determinants Det $J$, Det $J_{Pi}$, and Det $J_{Xi}$ would be $6 \times 6$. The expansion of an $n \times n$ determinant has $n!$ terms. Changing from the $5 \times 5$ determinants of this paper to $6 \times 6$ determinants would multiply by six the number of terms in the expressions of the first-order equilibrium conditions. Another desirable extension would relax the assumption that $X_0$ is fixed and would allow $X_n$ to vary independently of $X_m$. This extension would add another equation to the model.

## Summary

This paper argues that further theoretical investigations of cooperative behavior are needed. It presents and analyzes a model of a bargaining cooperative that bargains for the price of its members' product, provides one service to members with no direct charge, and sells another service to members and nonmembers. First-order equilibrium conditions are presented for two possibilities: a cooperative that maximizes member price and a cooperative that maximizes volume of raw material marketed under its management. The first-order conditions are quite different in the two cases, and both differ from the first-order conditions for a profit-maximizing proprietary firm. The first-order conditions presented here show that an efficient $P_m$ maximizer does not behave in the same way as an efficient $X_m$ maximizer. One uses (19), (21), and (24) to determine the values of $P_1$, $S_2$, and $S_3$. The other uses (25), (26), and (27) to determine the values of these three instrument variables.[7]


## A Methodological Note

The professor in a graduate course in microeconomic theory told the author: "The purpose of theory is not to provide answers but to help us ask the proper questions." Theoretical analyses (whether mathematical, as in this paper, or graphic, or verbal) can help in selection of the proper questions, but cannot provide answers. To cite some examples from this paper, the striking differences between (19) and (25), between (21) and (26), and between (24) and (27) point out the importance of asking questions about the cooperative's objectives. Expression (19) shows that to determine the optimum level of service one for a maximizer of $P_m$, it is necessary to answer the questions: What are the marginal revenue and marginal cost functions for service one? What are the values of $(\partial P_m/\partial P_1)_1$, of $(\partial P_m/\partial X_m)_1$, and of the other partial derivatives on the right-hand side of equation (19)?[8]

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[7] This paper shows that equilibrium conditions are sensitive to variation in assumed objectives. It is also true, though not shown in this paper, that first-order equilibrium conditions are affected by variations in the model. For example, assuming that the first service is sold only to members, that members purchase all their supplies of this production input from the cooperative, and that the amount purchased by members is independent of prices and is proportional to $X_m$, $(S_1/X_m = \alpha)$ yields first-order conditions quite different from the ones presented here.

[8] The evidence cited in footnote 7 shows that it is also necessary to answer the question: What is the appropriate set of behavioral equations to include in the model?

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# APPENDIX

## List of Variables

All variables used in this paper are listed and defined here. The number following the definition identifies the numbered equation in which the variable first appears.

$X_m$ = quantity of raw product produced by cooperative members: eq. (1)
= quantity of raw product marketed under the management of the cooperative

$X_n$ = quantity of raw product produced by nonmembers: eq. (1)

$X_0$ = total quantity of raw product $= X_m + X_n$: eq. (1)

$P_1$ = price charged by the cooperative for the first service—the productive input sold to members and nonmembers: eq. (2)

$P_c$ = price charged by other firms for the first service: eq. (2)

$P_m$ = price received by members from the cooperative for their raw product: eq. (2)

$P_n =$ price received by nonmembers for their raw product: eq. (2)

$S_2 =$ amount of second service provided to members by the cooperative: eq. (2)

$S_1 =$ total quantity of the first service sold by the cooperative: eq. (3)

$P_0 =$ price received by the cooperative from processors for the members' raw product: eq. (4)

$S_3 =$ quantity of bargaining service performed by the cooperative: eq. (4)

$C = C(S_1, S_2, S_3, X_m) =$ cooperative's total cost function: eq. (5)

$D =$ difference between price paid to the cooperative and price received by nonmembers for raw material: eq. (6)

$R_1 = P_1S_1 =$ cooperative's total revenue from sale of first service: eq. (8.1)

# A Macro-Economic Model for Agricultural Sector Analysis*

**Derek Byerlee and A. N. Halter**

**Agricultural sector analyses for purposes of agricultural policy evaluation and planning in developing countries are generally conducted in a partial equilibrium framework without regard to agricultural-nonagricultural interactions. A relatively simple simulation model built on an input-output framework is developed which, in combination with an agricultural sector analysis, enables interactions in the product markets and labor market to be considered. The model is illustrated through linkage with an agricultural simulation model to evaluate alternative agricultural policies in Nigeria. The model also has potential for use with other formal and informal sector analysis techniques.**

***Key words:*** **sector analysis, agricultural planning, input-output, Nigeria.**

Growing awareness of the importance and special problems of planning agricultural development has led to an interest in agricultural sector analysis, that is, the process of policy evaluation with respect to specified goals at the sector level. By enabling a consideration of *intra*-sectoral relationships and the dynamic processes of the growth of a sector, agricultural sector analysis narrows the gap in conventional planning approaches between micro-economic, often *ad hoc* project appraisal, and macro-economic projections of national accounting variables.

Agricultural sector analyses have varied widely in scope and problem orientation. Analytical techniques employed range from informal projections (e.g., Johnson *et al.* [17] and Fletcher *et al.* [11]) to linear and recursive linear programming (e.g., Duloy and Norton [8] and Singh [26]) to the systems simulation approach (Manetsch *et al.* [21]).[1] But regardless of the approach adopted, all sector studies are faced with the problem of analyzing interactions between the agricultural sector and other sectors of the economy.

In developing countries where the agricultural sector often accounts for over half the national income and an even higher proportion of total employment, recognition of agricultural-nonagricultural interactions is clearly important to agricultural sector analysis. There are flows of goods and services between the agricultural and nonagricultural sectors through the product markets for purposes of consumption, production, and investment. Furthermore, agriculture and nonagriculture interact in the factor markets to determine allocation of capital, labor, and foreign exchange between the two sectors.[2] Thus variables of the nonagricultural sector are not exogenous to the agricultural sector. In particular, the level of nonagricultural income used by a sector analyst to project nonagricultural food demand is likely to be significantly influenced by agricultural variables such as agricultural export earnings and the demand of the agricultural population for nonagricultural goods and services. Moreover, the sector analyst in policy evaluation should be concerned with the indirect effects of agricultural policies on the nonagricultural sectors. For example, agricultural policies for saving foreign exchange through food self-sufficiency may have favorable effects on the agricultural economy, but through increases in food prices and agricultural investment may have a high opportunity cost in the nonagricultural sectors.

Approaches to incorporating agricultural sector analyses into a general equilibrium or macro-economic framework have varied widely. Johnson *et al.* [17] in an agricultural sector analysis of Nigeria used a crude method in which changes in nonagricultural value added are related to changes in agricultural value added through a fixed demand multiplier.[3] This method, of course, ignores the complexity of agricultural-nonagricultural interactions in product and factor mar-

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[1] See Thorbeck [27] for a review of recent developments in agricultural sector analysis.

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[2] See Johnston and Mellor [18] for a detailed discussion of the relevance of agricultural-nonagricultural interactions in economic development.

[3] See Cownie [6] for more details.

kets. At the other extreme, the Duloy and Norton [8] model of the agricultural sector of Mexico can in theory be explicitly linked to a large programming model of the national economy (Goreux [13]). While agricultural-nonagricultural interactions can be considered in detail in this model, the general applicability of the approach is limited by the lack of an appropriate macro-economic model in most countries and the practical difficulties of interfacing two large models.[4] Alternatively Fletcher *et al.* [11] and Thorbecke and Sengupta [28] use a simple macro-economic model to make projections of the total economy which are then used in the agricultural sector analysis. This approach assumes that agricultural development strategies will not affect the overall growth and structure of the economy, thereby ignoring an important role for agricultural sector analysis. Finally, the simplest and most common approach is to treat the nonagricultural economy exogenously, a critical limitation to realistic sector analysis.[5]

It is the purpose of this paper to describe and illustrate a simple but dynamic macro-economic model which, by interacting with an agricultural sector model, explicitly considers the various agricultural-nonagricultural interrelationships so that variables of a sector analysis (such as agricultural income, exports, and employment) can be made consistent with other sectors of the economy and with overall macro-economic variables as illustrated in Figure 1. An essential feature of the model is both its relative simplicity and its flexibility to handle sector analyses based on various analytical techniques. Its simplicity is particularly important where the sector analyst does not have access to a detailed macro-model and does not have the resources to build one. Likewise, the model is flexible since it can interact with informal sector analyses by iterative methods to ensure consistency between variables of the agricultural sector and the macro-economy or alternatively, as in the empirical example developed below, a formal sector model and the macro-economic model can be explicitly coupled to facilitate computations.[6]

In this paper the authors first describe the model generally and then allow it to interact with an agricultural sector-simulation model developed by Manetsch *et al.* [21] to illustrate its use for agricultural policy analysis in a particular country, Nigeria.

[4] In fact, this linkage has for practical reasons not been formally accomplished. See Goreux [13, pp. 50–51].

[5] This approach is commonly used in informal sector analyses (e.g., Food and Agriculture Organization [9]), although some formal models such as Singh [26] also ignore agricultural-nonagricultural interactions.

[6] This distinction between informal and formal sector analyses follows Thorbecke [27].

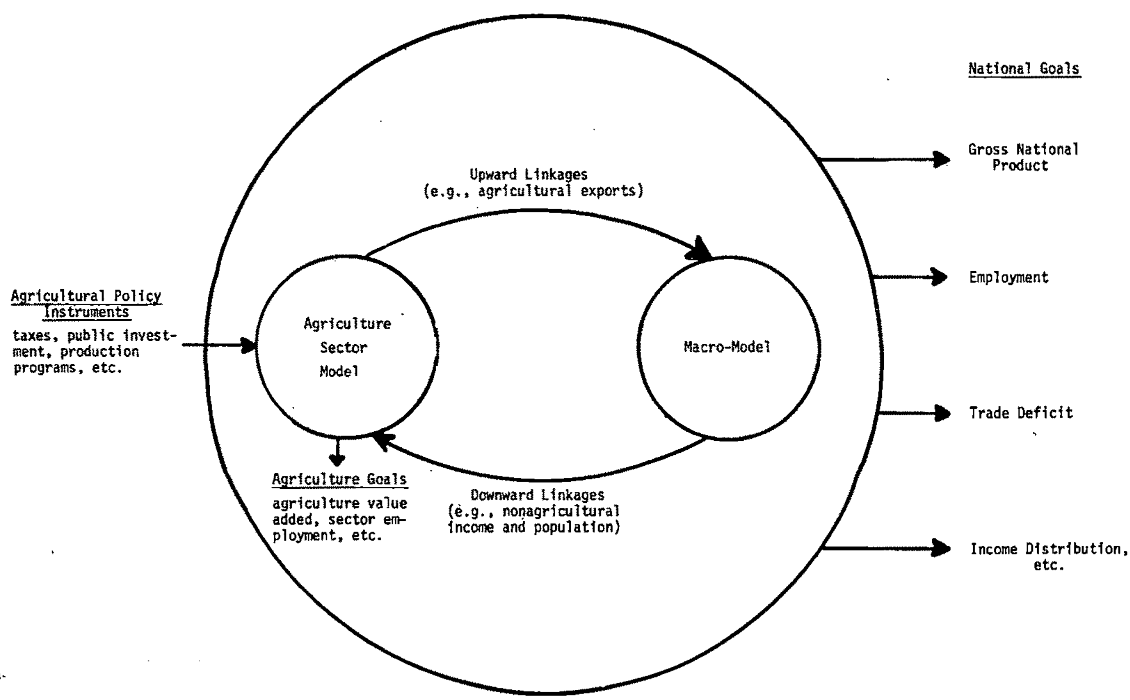


Figure 1. The macro-economic model in a policy framework

## The Structure of the Macro-Economic Model

The model is a simple simulation model built on an input-output framework.[7] It disaggregates the total economy into a number of interacting sectors of interest. A unique feature is the emphasis on firm size in addition to the conventional industrial classification in defining sectors. Thus, there are four small-scale sectors—main agricultural crops, residual agricultural crops, small industry, and small trade-services—all composed of firms employing less than 10 persons.[8] These firms generally use family labor and traditional methods of production. The remaining sectors—mining, construction, transport, utilities, large industry, and large trade-services—are large-scale and include only establishments employing 10 or more persons. Modern, capital intensive methods of production are common in these sectors. Since the small-scale sectors are generally more labor intensive and produce commodities satisfying different consumer income classes, this distinction on the basis of scale of industry facilitates incorporation of employment and income distribution as policy goals.

The model is also broken down into various components: (a) consumption, (b) investment, (c) output, (d) employment-incomes, and (e) national accounts, as shown in Figure 2. At the beginning of each time period, consumption and investment are generated endogenously in separate components of the model. Exports are computed exogenously and aggregated with consumption and investment to give total final demands from each sector for domestic production. Using conventional input-output techniques, these final demands are translated in the output component into interindustry flows, intermediate imports, and value added for each sector. An important feature of the model is the employment-incomes component which simulates demands for employment and incomes in each sector, a Gini-ratio of income distribution, and the migration of labor out of agriculture. These results are then used in the construction of the national accounts and the computation of consumption,

[7] For a similar regional application of this type of model see Doeksen and Schreiner [7].

[8] See Table 2 for details of the composition of each sector.

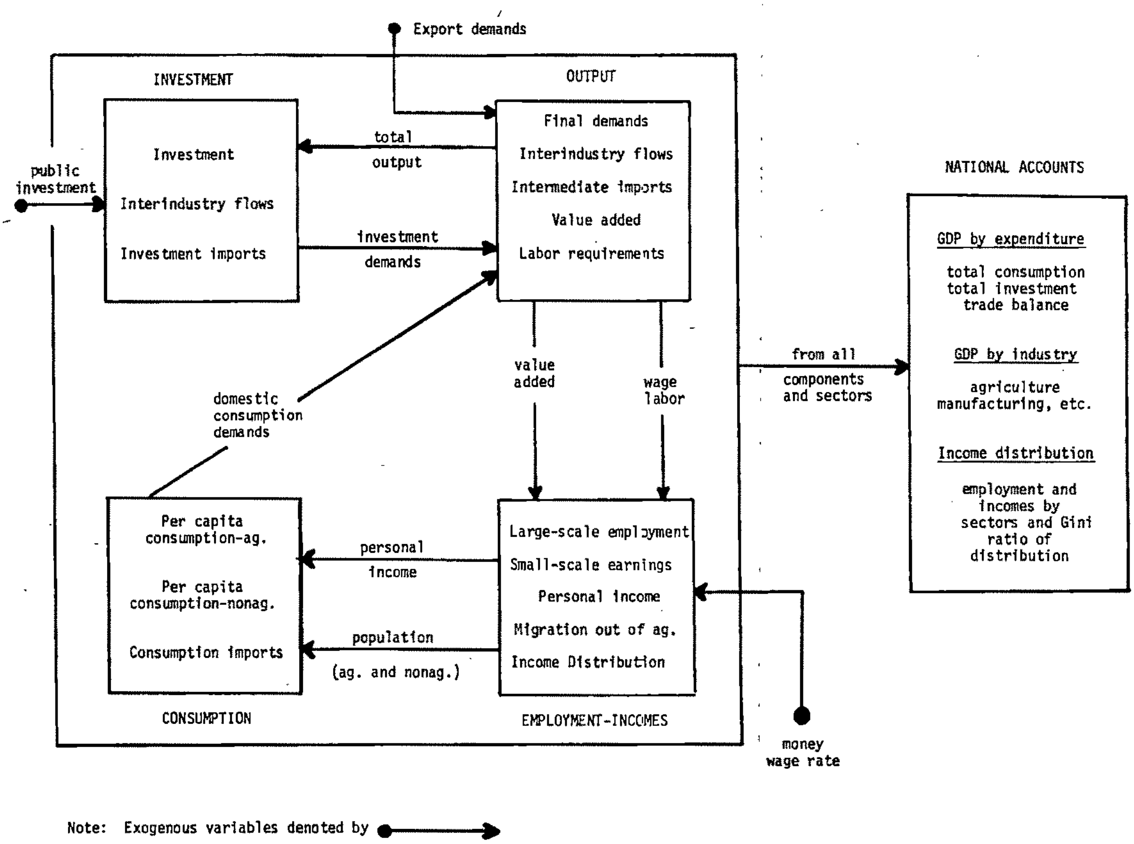


Figure 2. The components of the macro-model and the main output variable of each component

investment, and employment in succeeding time periods.

A detailed description in the variables of each of the model components (i.e., consumption, investment, output, employment-incomes, and national accounts) follows. Many of the variables relating to the agricultural sector will of course be computed in an agricultural sector analysis as discussed later.

## Consumption

The consumption component simulates the demands by various classes of consumers for domestically produced and imported goods and services. Consumption is disaggregated into 10 goods corresponding to the 10 sectors of the model and two population classes—agriculture and nonagriculture. Thus, $c_{ir}(t)$, the per capita consumption of the $i$th good by the $r$th population class is modeled by equation (1) as a function of personal income, $y_r^d(t)$,[9] and the price of food relative to nonfood goods, $p_f(t)$.[10] The ideal of breaking down consumption into income classes was not possible with the data available, but the disaggregation of consumer behavior by agricultural and nonagricultural populations does provide for some variation on consumer behavior by income class.

$$(1) \quad c_{ir}(t) = a_{ir} y_r^d(t)^{\epsilon_{ir}} p_f(t)^{\eta_{ir}} \qquad i = 1, \ldots 10, r = 1, 2$$

where $\epsilon_{ir}$ is the income elasticity of demand for the $i$th good by the $r$th population class and $\eta_{ir}$ is the corresponding elasticity with respect to staple food prices.

The demand for goods and services is summed over all consumers in equation (2) to give total consumer demand, $C_i(t)$. Total population is assumed to grow at a fixed rate, but because of migration out of agriculture (determined endogenously in the employment-incomes component), the nonagricultural population $N_2(t)$ grows at a faster rate than agricultural population $N_1(t)$. Finally, in equation (3), imports of consumer goods, $M_i^c(t)$ are determined as a proportion $m_i^c(t)$ of total consumption. This proportion varied exogenously over time to reflect import substitution:

$$(2) \quad C_i(t) = \sum_{r=1}^{2} N_r(t) c_{ir}(t)$$

$$(3) \quad M_i^c(t) = m_i^c(t) C_i(t).$$

## Investment

Investment in each sector is determined in part exogenously and in part endogenously.[11] Public investment is the largest component of exogenous investment. This investment is concentrated in the large-scale sectors, particularly transportation, utilities, and services. In addition, private investment in the agricultural and mining sectors is treated exogenously—in agriculture because investments can be estimated more realistically in a sector analysis and in mining because investment in mineral exploration has long run uncertain pay-offs which render a capital-output ratio meaningless.

Private investment in other sectors $\Delta K_j(t)$ is modeled through the use of a capital-output ratio, $k_j$, and the accelerator principle using equation (4). These investment requirements in the $j$th sector are then used to determine demand for capital goods, $I_i(t)$ from the $i$th sector in equation (5).[12] However, for the construction sector, $i = 7$, investments by households in residential construction represent a considerable source of demand. This is modeled in equation (6) as a function of personal income, $y_r^d(t)$,

$$(4) \quad \Delta K_j(t) = k_j X_j^d(t) \qquad i = 1, \ldots 10$$

$$(5) \quad I_i(t) = \sum_{j=1}^{10} b_{ij}[\Delta K_j(t) + \Delta K^*_j(t)] \qquad i = 1, \ldots 10, i \neq 7$$

$$(6) \quad I_7(t) = \sum_{j=1}^{10} b_{7j}[\Delta K_j(t) + \Delta K^*_j(t)] + \sum_{i=1}^{2} a_r^h N_r(t) y_r^d(t)^{\epsilon_r^h}$$

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[9] In fact, $y_r^d(t)$ is the exponentially lagged value of personal income, using the equation

$$y_r^d(t) = y_r^d(t - dt) + (dt/L)[y_r(t) - y_r^d(t - dt)]$$

where $dt$ is the time interval of a simulation interaction, $y_r(t)$ is the current value of personal income, and $L$ is the average length of the lag. Personal income is computed in the employment-incomes component as the sum of wages and nonlabor income in large-scale sectors and earnings in small-scale sectors. Personal income in agriculture will normally be computed in an agricultural sector analysis.

[10] Prices are exogenous to the macro-economic model. However, food prices will usually be endogenously determined in an agricultural sector analysis.

[11] The distinction here between exogenous and endogenous investment is analogous to Jorgensen's [19] classification of investment as "autonomous" and "induced."

[12] This corresponds to the "B" matrix of input-output analysis.

where $X_j^d(t)$ is the exponentially lagged value of the output of the $j$th sector, $b_{ij}$ is the demand for capital goods from the $i$th sector generated by one unit of investment in the $j$th sector, $\Delta K^*_j(t)$ is exogenously determined investment in the $j$th sector, and $\epsilon_r^h$ is a demand elasticity for housing.

Finally, in an analogous manner to consumption, total investment is divided in equation (7) between domestically produced and imported capital goods:

$$(7) \qquad M_i^I(t) = m_i^I(t)I_i(t).$$

### Output

Given investment, consumption, and an exogenous specification of exports,[13] conventional input-output techniques are used to compute output, value added, imports, and other national accounting variables such as GNP. The vector of sector outputs, $X(t)$, is given by equation (8) where $I^o$ is the identity matrix, $A$ is the input-output matrix, and $C(t)$, $I(t)$, and $E(t)$ are vectors of consumption, capital good demands, and exports, respectively:

$$(8) \quad X(t) = [I^o - A(t)]^{-1} [C(t) + I(t) + E(t)].$$

Imports for intermediate use, $M_i^N(t)$, are determined in equation (9) through a set of coefficients $m_i^N(t)$. Value added in each sector is then easily obtained in equation (10).

$$(9) \qquad M_i^N(t) = m_i^N(t)X_i(t)$$

$$(10) \quad V_i(t) = X_i(t) - \sum_{j=1}^{10} a_{ij}X_i(t) - M_i^N(t).$$

### Employment and incomes

The employment-incomes component models the nonagricultural labor market and migration to provide employment and incomes by sector.

**The nonagricultural labor market.**—The nonagricultural labor market is disaggregated into: (1) employment in the large-scale sectors where the wage rate is institutionally fixed and (2) employment in the small-scale sectors where earnings are determined by supply and demand.[14] Employment, $L_i^w(t)$, in each of the *large-scale* nonagricultural sectors ($i = 5, \ldots, 10$) is assumed to grow at the same rate as output of that sector, $X_i(t)$, with exogenous adjustments, $r_i$, for productivity increases as in equation (11).[15]

$$(11) \quad L_i^w(t) = l_i(t)X_i(t) \qquad i = 5, \ldots 10$$

where $l_i(t)$ is the labor input per unit of output in the $i$th large-scale sector and is defined as $l_i(t) = l_i(t - dt)\ [1 - r_i dt]$. The money wage rate in each of the large-scale sectors, $\overline{W}_i(t)$, is exogenously specified in the model reflecting the dominance of institutional forces in determining this wage rate. The wage rate in the public sector $\overline{W}_g(t)$ is also exogenously specified. Employment in this sector, $L_g^w(t)$, is determined in equation (12) by the size of the recurrent budget, $G(t)$, and inversely related to the wage rate.

$$(12) \qquad L_g^w(t) = G(t)/\overline{W}_g(t).$$

The remainder of the nonagricultural labor force, $L^s(t)$, is assumed to be employed in the small-scale nonagricultural sectors ($i = 3, 4$). Average earnings in the nonagricultural small-scale sectors $W_s(t)$ are computed by equation (13), from the sectoral value added, $V_i(t)$, obtained from the output component:

$$(13) \qquad W_s(t) = \sum_{i=3}^{4} P_i V_i(t)/L^s(t),$$

where $P_i$ is the proportion of the value added of the $i$th small-scale sector accruing to workers after reinvestment of profits and taxes.

Although the model does not explicitly compute urban unemployment, earnings in the small-scale sector act as a useful proxy variable for unemployment and underemployment in those sectors.

**Migration.**—The modeling of migration of the labor force out of the agricultural sectors is based on an extension of the Harris-Todaro [15] model. That is, the proportion of the agricultural population that migrates in a given year, $M(t)$, is determined in equation (14) by an exponentially lagged response, $D$, to changes in the expected agricultural-nonagricultural income differential, $d[W_a/E(W_n)]/[W_a/E(W_n)]$:

[13] In actuality, agricultural exports are endogenously determined in agricultural sector analysis.

[14] See Byerlee and Eicher [3] and Kilby [20] for evidence supporting the applicability of this type of dual labor market.

[15] The index $i$ in Equation (5) ranges from $i = 5, \ldots, 10$ corresponding to the six large-scale sectors of the model.

$$(14) \quad M(t) = M(t - dt) \left[ l + \beta D \left( \frac{d\left[\frac{W_a}{E(W_n)}\right]}{\frac{W_a}{E(W_n)}} \right) dt \right],$$

where $W_a$ is the average real earnings in the agricultural sector, $E(W_n)$ the expected nonagricultural income,[16] and $\beta$, $\beta < 0$, is the elasticity of migration with respect to changes in the agricultural-nonagricultural differential—an important parameter of the model.

This formulation of the nonagricultural labor market and migration yields employment and personal income per worker by sector. In this way the model can be used to provide an aggregate measure of income distribution by a functional breakdown of personal income in a manner similar to Thorbecke and Sengupta [28].[17]

### National accounts

At the end of each series of computations the model constructs a series of national accounts. This is a simple accounting procedure aggregating results from all components of the model. For example Gross Domestic Product, $GDP(t)$, and the balance of trade, $B$, are computed in equations (15) and (16):

$$(15) \quad GDP(t) = \sum_{i=1}^{10} V_i(t) + G(t)$$

$$(16) \quad B = E^T(t) - M^T(t)$$

where $G(t)$ is exogenously determined government value added and

$$M^T(t) = \sum_{i=1}^{10} [M_i^c(t) + M_i^I(t) + M_i^N(t)].$$

Furthermore the model output includes summaries of employment and earnings by sector. These accounts form the basis for evaluating agricultural policies with respect to national goals such as $GDP$, employment, and income distribution.

### Interaction of the Macro-Economic Model and an Agricultural Sector Model

The macro-economic model has value in making general projections of variables such as $GDP$, employment, and income distribution which are internally consistent. However, as with most macro-economic models and particularly input-output models, it can only give very general policy inferences relating to possible bottlenecks in the economy. The model's usefulness for specific policy analysis lies in its ability to incorporate a sector analysis into a broader macro-economic framework. Essentially, this involves "dissecting" out the agricultural sector of the macro-model and allowing variables of this sector to be computed in a detailed agricultural sector analysis and passed "upward" to the macro-model. Examples of such variables are given in Table 1. All these variables can be explicitly related to agricultural policy instruments in a sector analysis but not in a macro-model. For example, in the macro-economic model, agricultural exports are included as an exogenous time series, while in a sector analysis exports can be projected through detailed analysis of supply and demand relationships and related to policy variables such as export pricing and investment strategies.

The interaction between a sector model and the macro-economic model is reciprocal. The macro-economic model provides estimates of population, urban food demands, and migration for use in a sector analysis (see Table 1). Variables are transferred iteratively through both upward and downward linkages between the sector analysis and the macro-model to ensure consistency.[18]

The macro-economic model can interact with both informal and formal sector analyses. In empirical applications discussed below, the macro-economic model is formally linked to a model of the Nigerian agricultural sector de-

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[16] The expected nonagricultural income, $E(W_n)$, is computed in the following equation from the probabilities that a migrant will find a wage job in the $i$th large-scale sector, the government sector, or alternatively be forced into lower paying small-scale employment with earnings $\overline{W}_i$, $\overline{W}_g$, and $W_s$ respectively.

$$E(W_n) = \frac{L^s(t)W_s(t) + H\left[\sum_{i=5}^{10} L_i^w(t)\overline{W}_i(t) + L_g^w(t)\overline{W}_g(t)\right]}{L^s(t) + \sum_{i=5}^{10} L_i^w(t) + L_g^w(t)}$$

where $L^s$, $L_i^w$, and $L_g^w$ are the number employed in small-scale sectors, in the $i$th large-scale sector, and in the government, respectively. $W_s$, $\overline{W}_i$, and $\overline{W}_g$ are adjusted downward by consumer price indices to reflect the higher cost of living in urban areas.

[17] See Byerlee [2] for more details.

[18] The use of the terms "upward" and "downward" linkages follows Goreux [13].

Table 1. Types of variables transferred between the macro-economic model and a sector model

| Variables Transferred from Agricultural Sector Model to Macro-Economic Model (Upward Linkages) | Variables Transferred from a Macro-Economic Model to a Sector Model (Downward Linkages) |
|---|---|
| 1. Agricultural exports and imports | 1. Nonagricultural incomes |
| 2. Investment in agriculture | 2. Nonagricultural population |
| 3. Agricultural incomes | 3. Demand for agricultural goods for intermediate use |
| 4. Agricultural employment | 4. Available labor supply to agriculture after migration |
| 5. Input-output coefficients for agriculture | |
| 6. Agricultural prices | |

veloped by Manetsch *et al.* [21]. This is a relatively large simulation model consisting of two interacting sub-models—the northern sub-model and southern sub-model—each of which is further disaggregated into four ecological regions corresponding to crop type. Both submodels compute land and labor allocation endogenously, although this is simplified by the assumption that land is surplus in the North and labor is surplus in the South. Allocation of land and labor as well as adoption of improved production techniques and new varieties are based on profitability criteria.

A fuller description of the agricultural model is contained in Manetsch *et al.* [21] and articles by Halter *et al.* [14], Hayenga *et al.* [16], and [22] in this *Journal.* It is sufficient here to note that the agricultural model simulates the effects of two broad types of policy instruments —export tax policies to influence the producer price for export crops and public expenditures to promote improved production methods and adoption of new varieties through credit and extension campaigns and input subsidies for both food and export crops. In this way variables of the agricultural sector such as agricultural exports, staple food prices, and input-output coefficients are computed in the agricultural model as a function of agricultural policy instruments and used in the macro-economic model. Likewise output variables of the macro-economic model such as nonagricultural incomes are used in the agricultural simulation model.

## Model Application and Validation in Nigeria

The macro-economic model has been used for agricultural policy analysis in Nigeria.[19] Data for the model were estimated from various sources and by various means, including regression analysis. For example, consumption data were estimated from household expenditure surveys, and parameters of the investment component were obtained from Clark [5]. The input-output table shown in Table 2 was constructed using data assembled by Carter [4].[20]

An essential test of a simulation model is its ability to describe the real world. The model will simulate time series of output variables after being initiated at some given year. Because the Nigerian input-output table and other data used in the model are based on the year 1959, runs of the macro-model described in this study are initiated in that year. The series of computations described in the previous section are then performed at quarter-year intervals up to the time horizon of interest. From 1959 to 1967 the model simulates results which can be compared with real world data to check the accuracy of the model. When the model has been confidently validated for this period, it can be used to predict the future path of the economy under alternative policy assumptions.

Formal statistical procedures often used for validating simulation models (e.g., Naylor [23]) were not used. Rather, a less formal method was devised where average annual growth rates of macro-economic variables simulated by the model were compared to actual growth rates derived from the official accounts.[21] The period 1960–1966 was used as a basis for the computation of the average growth rates.[22] The variables

[19] A similar approach is also being used for agricultural policy analysis in Korea in an extension of the work of Rossmiller *et al.* [25].

[20] See Byerlee [1] for more details on the parameters of the model.

[21] Comparison of absolute values of macro-economic variables was not possible since the model was based on Carter's [4] estimates of the national accounts in 1959 which differ from official estimates for that year.

[22] That is, the year 1959 (i.e., four iterations) was allowed for the model to attain a growth path indepen-

Table 2. Input-output coefficients of the Nigerian economy for 1959[a]

| Production-Scale | Small-Scale 1 | 2 | 3 | 4 | Large-Scale 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Small-Scale | | | | | | | | | | |
| 1. Main Agriculture | .000 | .000 | .085 | .000 | .006 | .000 | .000 | .000 | .137 | .000 |
| 2. Residual Agriculture | .000 | .000 | .068 | .000 | .000 | .092 | .000 | .037 | .025 | .000 |
| 3. Small Manufacturing | .001 | .001 | .000 | .008 | .006 | .021 | .045 | .068 | .015 | .010 |
| 4. Small Trade-Services | .001 | .003 | .040 | .000 | .012 | .067 | .016 | .019 | .007 | .028 |
| Large-Scale | | | | | | | | | | |
| 5. Mining-Oil | .000 | .000 | .001 | .000 | .000 | .051 | .008 | .079 | .007 | .000 |
| 6. Construction | .000 | .000 | .000 | .003 | .007 | .000 | .000 | .004 | .002 | .019 |
| 7. Transport | .003 | .063 | .037 | .018 | .018 | .079 | .000 | .054 | .027 | .013 |
| 8. Utilities | .000 | .005 | .002 | .000 | .020 | .001 | .000 | .000 | .014 | .007 |
| 9. Large Manufacturing | .000 | .000 | .021 | .002 | .007 | .029 | .023 | .023 | .000 | .011 |
| 10. Large Services | .004 | .003 | .037 | .023 | .012 | .010 | .028 | .018 | .037 | .000 |
| Imports | .016 | .014 | .197 | .009 | .223 | .228 | .113 | .135 | .232 | .031 |

Source: Adapted from Carter [4].

[a] The composition of each sector is: (1) main agriculture—main export crops (i.e., cocoa, rubber, palm, cotton, groundnuts), food staples, and cattle; (2) residual agriculture—other crops and livestock, fishing, and forestry; (3) small industry—carpentry, weaving, shoemaking, and other crafts; (4) small trade-services—petty trading and services; (5) mining—metal and nonmetal mining and oil; (6) construction—residential housing, private and public construction projects; (7) transport—rail, boat, road, and air; (8) utilities—electricity and water; (9) large manufacturing—processed food, drink, tobacco, chemicals, and metal manufacturing; and (10) large-trade services—large-scale trading companies, banking, and insurance.

used in the validation process are shown in Table 3. These include three national income variables—gross domestic product, investment, and imports. Average growth rates in value added by sector were also used to compare simulated and actual results.[23]

The results from two validation runs of the model are illustrated in Table 3. In the first run, all import coefficients, except the import coefficients for consumption, were fixed throughout the run. Generally, the growth rates simulated by the model were of the same order of magnitude as observed in the real world. However, from the results some general inferences can be made for improvement of the model's performance. The model simulated a relatively low growth rate of *GDP*, a high growth rate of imports, and a low growth rate for the large manufacturing sector. This would suggest that the model fails to account for some import substitution. A further series of runs was made with changes in some of the static coefficients for imports in the production and consumption components.[24] The results given in Table 3 show an even closer agreement between simulated and actual growth rates, particularly in the large manufacturing sector. Clearly such "tuning up" of the model could be carried on indefinitely, but the limitations of the real world data and the "good fit" of the model did not warrant further adjustments.

The method of validation used here enables considerable confidence to be placed on the model's ability to simulate the major trends in the economy over a six-year period. However, even casual comparison of the model's results with the real world showed that the model is not capable of simulating year-to-year fluctuations. To some extent this may reflect deficiencies in the structure of the model, but it is likely that fluctuations in the Nigerian economy are also due to random disturbances such as weather and export price variability. Furthermore, for plan-

dent of the initial conditions. Also, following 1966 the economy was distorted by the outbreak of civil disturbances.

[23] The sectors defined in the model did not always correspond with the sectoral breakdown of value added in the official national accounts, and satisfactory comparison could only be made for five sectors: agriculture, total nonagriculture, large manufacturing, construction, and transport.

[24] From the study of import substitution in Nigeria by Clark [5], two major shifts in coefficients can be detected. First, the import content of investment in the craft and textile industries over the period 1959–1965 dropped from 70 percent to 20 percent, with most of the increased domestic production being supplied by the large manufacturing sector. Second, the coefficients of the mining-oil sector indicated a relatively greater requirement for domestic manufacturers and construction as oil became dominant in this sector.

Table 3. Comparison of simulated growth rates and historical growth rates of some macro-economic variables

| | Real World Data[a] | Simulated Run with Fixed Import Coefficients | Simulated Run with Import Substitution |
|---|---|---|---|
| | Average annual growth rates 1960–1966 | | |
| Gross Domestic Product | 5.8 | 5.1 | 5.4 |
| Total Investment | 8.7 | 8.8 | 9.0 |
| Total Imports | 4.0 | 6.4 | 6.0 |
| Value Added—Agriculture | 3.7 | 3.5 | 3.6 |
| Value Added—All Nonagriculture | 8.0 | 6.5 | 7.0 |
| Value Added—Large Manufacturing | 14.0 | 9.5 | 13.6 |
| Value Added—Construction | 9.7 | 8.5 | 9.7 |
| Value Added—Transport | 5.4 | 4.4 | 4.6 |
| Large-Scale Employment | 2.5 | 2.7 | 3.0 |
| Earnings/Worker in Small-Scale Nonagriculture | <0 | —1.1 | —.5 |

[a] Sources: Growth rates for gross domestic product, investment, and imports are based on data reported in Vielrose [29]. Sectoral growth rates are calculated from estimates in Federal Office of Statistics [10]. Growth rates for wage employment and small-scale earnings per worker are from Frank [12] and Kilby [20].

ning in developing countries, longer run trends are more important than short-run fluctuations.

## The Model Applied to Agricultural Policy Analysis

Although the agricultural sector model is capable of simulating the effects of a large number of alternative policies, to illustrate the use of the model in policy analysis, only two broad agricultural strategies are analyzed: export crop promotion and food crop promotion. These strategies are within the feasible range of policy options faced by Nigerian planners today.[25]

The policy runs demonstrating export crop and food crop production strategies are shown in Table 4 where the policy instruments considered are the allocation of public expenditures between food and export crops and the level of taxation of export crops. The year 1983 is chosen to represent a medium-term planning horizon of 10 years into the future for evaluating policies. A shorter period allows insufficient time for agricultural strategies, particularly for perennial crops, to have their full effect while a longer planning horizon strains the structural rigidities of the model inherent in the use of static input-output coefficients and capital-output ratios. All policy runs are evaluated with respect to a base run which assumes continuation of present agricultural policies and exogenous projections of some variables such as oil exports and government revenues.[26] Finally, for this brief illustration, the effects of policies are analyzed only with respect to output variables of the macro-economy and ignoring employment and income distribution effects which are considered in detail in further application of the model by Byerlee [2].

### The export promotion strategy

An export promotion strategy which includes increasing produce prices and export crop production campaigns is shown in Run 1 of Table 5. Agricultural exports at world prices more than double. This increase in exports produces an increase of £451m in agricultural value added at current prices by 1983, but in real terms this increase is only £390m because of a 2.6 percent rise in food prices (line 4, Table 5). The increase in food prices is a result of both increased demand for food with higher incomes and reduced supply in areas where food crops and export crops compete. This real increase in agricultural value added can be partitioned into a direct effect of £303m as a result of increased exports and an induced effect of £87m as a result of (a) an induced effect on consumption of food due to higher incomes of both the agricultural and non-agricultural populations, (b) increased demands for agricultural raw materials for intermediate use, and (c) an induced effect on investment stimulated by increased demands for raw materials and consumer goods. On the supply side, the agricultural labor force is increased by a decrease in out-migration and also contributes to the induced increase in agricultural production.

As a result of the increase in exports, non-

[25] Historically, Nigerian agricultural policy and sector analyses have emphasized exports as the "engine of growth" (e.g., Johnson *et al.* [17]). Recently, however, there has been increasing emphasis on promotion of food crops to steady rising food prices.

[26] In fact the growth of the oil industry is the most important exogenous influence on the economy. Oil export projections are based on the "optimistic" forecast of Pearson [24].

Table 4. Details of simulation runs used to analyze the macro-economic effects of alternative agricultural development strategies

| Run | Total Expenditure on Agricultural Production Campaigns[a] | Expenditure on Export Crop Promotion[b] | Expenditure on Food Crop Promotion[c] | Average Taxation of Export Crops |
|---|---|---|---|---|
| | £m[d] | £m | £m | Percent |
| Base Run | — | — | — | 25 |
| Export Promotion Strategies—Run 1 | 12.5 | 12.5 | — | 0 |
| Food Promotion Strategies—Run 2 | 12.5 | — | 12.5 | 25 |
| Combined Strategy—Run 3 | 12.5 | 8.5 | 4.0 | 0 |

[a] Relative to Base Run. Expenditures are spread over a 10-year period beginning in 1965.
[b] More specifically, the export crop promotion strategy involves the promotion of new production techniques for cotton, groundnuts, oil palm, cocoa, and rubber.
[c] The food promotion strategy emphasizes the introduction of higher yielding varieties of food staples (e.g., maize, sorghum) and the use of fertilizers and chemicals.
[d] The exchange rate is approximately £1 = US $3.00.

agricultural value added increases by £373m because of a direct increase of £59m in value added resulting from marketing and transportation of agricultural exports (i.e., the forward linkages of agriculture) and indirect and induced effects of £314m.[27] The indirect and induced increase in nonagricultural value added can be separated into the indirect effect or backward linkages resulting from increased use of manufactured inputs, etc., in agriculture and an induced increase in consumption and investment of nonagricultural goods resulting from higher incomes. In fact, line 11 of Table 5 shows that agriculture's requirements for domestically produced inputs and capital goods are minor and most of the increases in nonagricultural value added result from induced increases in consumption (line 9) and its associated induced investment response (line 10). Because of the higher income elasticity of demand for nonagricultural consumer goods and because most investment goods are produced in the nonagricultural sectors, the *induced* effects of higher agricultural exports on the nonagricultural sectors are larger than in the agricultural sectors.

Increase in nonagricultural output is further broken down by small-scale and large-scale sectors in lines 8.3 and 8.4 of Table 5. Because most marketing and transportation of export crops are undertaken in the large-scale sectors, particularly large-services (sector 10), the impact of the export promotion strategy is more favorable for the large-scale sectors.

[27] The terminology here follows standard input-output methods. "Indirect" effects are the result of input-output multipliers while "induced" effects result from income multiplier effects on consumption and investment.

Finally, an important result of the export promotion strategy is the £180m increase in imports. That is, over half the foreign exchange earned is used to pay for higher levels of imports for production, consumption, and investment.

## The food promotion strategy

The most obvious effect of the food promotion strategy is a 15.5 percent decline in food prices in 1983 relative to the base run (Run 2, line 4).[28] This is explained by two critical assumptions of the agricultural sector model that Nigeria is self-sufficient in food staples, but production and marketing costs are too high to export food staples; and the demand for food is price inelastic.

The food promotion strategy results in only a small decrease in agricultural exports largely because there is little competition between export crops and *cash* food since areas that produce export crops produce only a small proportion of food for the cash market. Overall there is an 8.2 percent increase in value added in agriculture.

The food promotion strategy has a relatively small effect on the nonagricultural sectors. There is a direct effect, as a result of the marketing and transportation of food. Most of this is assumed in the model to accrue to the small-scale sectors, particularly small-services. The indirect and induced effects are very small. Although the lower food prices enable the non-

[28] However, in the food promotion strategy, food prices still rise at an average annual rate of increase of 1 percent between 1966–1983, compared with an average annual increase of 2 percent in the base run.

**Table 5. Effects of agricultural policies on macro-economic variables[a]**

| Macro-economic variable | Base Run | | Run 1 Export Promotion | | Run 2 Food Promotion | | Run 3 Balanced Food and Export Promotion | |
|---|---|---|---|---|---|---|---|---|
| | Value 1983 | Unit | Deviation from Base Run 1983 | Percent Deviation | Deviation from Base Run 1983 | Percent Deviation | Deviation from Base Run 1983 | Percent Deviation |
| 1. Agricultural exports (world prices) | 212 | £m | 306 | 144.2 | -.2 | -.1 | 230 | 136.7 |
| 2. Agricultural exports (Producer prices) | 123 | £m | 307 | 248.2 | -.1 | -.1 | 295 | 238.7 |
| 3. Total food consumption (constant prices) b/ | 804 | £m | 46 | 5.7 | 87 | 11.1 | 85 | 10.6 |
| 4. Market price of food staples | .0152 | £/lb | .0004 | 2.6 | .0022 | -15.5 | -.0015 | -9.9 |
| 5. Value added--agriculture (current prices) | 1563 | £m | 451 | 28.9 | -41 | -2.8 | 350 | 22.4 |
| 6. Value added--agriculture (constant prices) | 1121 | £m | 390 | 34.8 | 90 | 8.2 | 418 | 37.3 |
| 6.1. Direct effect c/ | -- | £m | 303 | | 78 | | 336 | |
| 6.2. Induced effect c/ | -- | £m | 87 | | 12 | | 82 | |
| 7. Agricultural labor force | 21.6 | m | .54 | 2.5 | -.06 | -.3 | .47 | 2.2 |
| 8. Value added--nonagriculture | 3082 | | 373 | 12.1 | 42 | 1.4 | 354 | 11.5 |
| 8.1. Direct effect d/ | -- | £m | 59 | | 30 | | 62 | |
| 8.2. Indirect and induced effects d/ | -- | £m | 314 | | 12 | | 292 | |
| 8.3. Small-scale sectors | 689 | £m | 52 | 7.5 | 21 | 3.1 | 53 | 7.7 |
| 8.4. Large-scale sectors | 2393 | £m | 312 | 13.0 | 21 | 0.9 | 301 | 12.6 |
| 9. Consumption of domestically produced nonagricultural goods | 1809 | £m | 330 | 18.2 | 16 | .1 | 315 | 17.4 |
| 9.1. Small-scale sectors | 744 | £m | 61 | 8.2 | 2 | .0 | 53 | 7.8 |
| 9.2. Large-scale sectors | 1065 | £m | 69 | 25.4 | 14 | .1 | 257 | 24.1 |
| 10. Demand for domestically produced capital goods | 675 | £m | 80 | 11.8 | 9 | 1.3 | 82 | 12.1 |
| 11. Agricultural requirements for domestically produced inputs and capital goods | 71.4 | £m | 7.7 | 10.7 | 5.2 | 7.3 | 7.1 | 10.0 |
| 12. Total imports | 1046 | £m | 180 | 17.2 | 11 | 1.1 | 170 | 16.3 |
| 13. Balance of trade | 216 | £m | 126 | 58.3 | -11 | -5.1 | 120 | 55.5 |
| 14. GDP at market prices (constant prices) | 4410 | £m | 763 | 17.3 | 132 | 3.0 | 772 | 17.5 |

a/ For details of individual simulation runs, see Table 4.

b/ Constant prices are based on 1960 price levels.

c/ The direct effect is the additional value added as a direct result of increased production with the agricultural policy. Induced effects result from changes in the demand for food and agricultural raw materials induced by changes in incomes.

d/ The direct effect is the additional value added as a result of marketing and transportation of agricultural products. Indirect and induced effects include all other changes in demands for nonagricultural output for consumption, production and investment.

agricultural population to purchase more nonagricultural goods, the decline in agricultural incomes counterbalances this effect. That is, purchasing power for nonagricultural goods is redistributed from the agricultural to nonagricultural population. There is, however, a slight shift in consumption toward the large-scale sectors (lines 9.1 and 9.2) because the higher income nonagricultural population has a slightly higher income elasticity for the output of some large-scale sectors, particularly utilities and large-scale manufacturers. Thus, the favorable direct effect of food production on the small-scale sectors is partly offset by the decline in demand for the output of these sectors resulting from lower agricultural incomes.

The above runs have assumed two divergent agricultural strategies, food promotion and export promotion. In the final run, Run 3, the development expenditure of £12.5m was divided between the export promotion strategy under reduced export taxes of Run 3 and the food

promotion strategy of Run 4.[29] Although agricultural exports are not as high as in Run 3, food consumption is increased by 10.6 percent partly in response to higher incomes and partly because of a 9.9 percent drop in the price of food. Overall this combination strategy produces the largest increase in agricultural value added of any of the runs discussed, giving rise to a 17.5 percent increase in *GDP*.[30]

## Some implications and limitations of the results

The macro-economic model enables most of the important linkages between the agricultural sector and other sectors to be captured. The direct effects, or more technically the "forward linkages" of the agricultural sector, accounted for about one-sixth of the total increase in nonagricultural value added in the case of export promotion strategies and almost all of the increase in the case of food promotion strategies. Moreover, unlike exports, most of these forward linkages of food production are in the small-scale sectors. The "backward linkages" of the agricultural sector (i.e., the demand generated by the agricultural sector for inputs and capital goods produced in the nonagricultural sectors) are particularly small in the Nigerian case, reflecting the negligible input-output coefficients of the agricultural sector (Table 2). Most of the effects of the agricultural policies on the nonagricultural sector result from the changes in demand for nonagricultural goods for consumption. Because the income elasticities for nonagricultural goods are higher than for food staples, most increases in agricultural incomes "leak" to the nonagricultural sectors causing a significant increase in nonagricultural value added. Increases in consumption expenditures also stimulate investment which also increases nonagricultural value added since most capital goods are produced in the nonagricultural sectors or imported.

In addition to flows of goods and services for consumption, production, and investment, the model accounts for out-migration from agriculture. This is important in determining both the supply of agricultural output where labor is limiting and the demand for cash food by the nonagricultural population.

There are several limitations to the macro-economic model in analyzing agricultural policy. First, it is deficient in modeling the capital market since it does not consider the transfer of savings between sectors. In particular the opportunity cost in the nonagricultural sectors of investment in agricultural production campaigns is not considered. Second, the model does not account for the "invisible" transfer of capital with lower food prices. Thus the lower food prices may decrease wages and stimulate investment. In the Nigerian context, however, the wages in the large-scale sectors do not appear to have been responsive to economic factors in recent years.[31] In the small-scale nonagricultural sectors where wages are competitively determined, there may be an increase in investment and an improvement in the ability of small-scale producers to compete with large-scale producers. Consideration of these interactions would cause the food promotion strategy to have more favorable long-run effects on the economy than predicted by the model. Third, the model is based on several static assumptions regarding nonagricultural supply. These include fixed capital output-ratios, exogenous specified import coefficients, constant nonagricultural prices, and an exogenously determined foreign exchange rate. In Nigeria where prices were until recently relatively stable and foreign exchange is now largely determined by oil exports, this deficiency is not a serious problem. Nonetheless, refinement of these supply aspects would enable conclusions to be reached regarding the allocation of public investment between agriculture and nonagriculture and provide more insights on the extent to which increases in agricultural incomes result in increases in nonagricultural production, higher prices, and increased imports.

Despite these limitations, the need for a sector-model interfaced with a macro-economic model is obvious from the results. Agricultural policies affect variables of the agricultural sector through induced changes in demand generated by agricultural-nonagricultural interactions. Furthermore, agricultural policies may have substantial effects on other sectors of the economy which should be of concern to the sector analyst. In the Nigerian policy evaluations, both the export and food promotion strategies increased agricultural value added significantly, but because of changes in terms of trade against agriculture associated

[29] See Table 4 for details of this policy run.

[30] Significantly, further explorations of the model show that this strategy also has the most favorable effects on employment and income distribution (see Byerlee [2]).

[31] See Kilby [20] for evidence of institutionally determined wages in Nigeria's large-scale sectors.

with the food promotion strategy, the effects on nonagricultural value added and hence macro-economic variables were very different. The macro-economic model while not in itself capable of policy analysis has provided valuable insights to the policy maker interested in the national implications of agricultural strategies.

## Conclusions

In the present paper the authors have described a macro-economic model which should be useful to an agricultural sector analyst who does not have the resources to build a detailed model of all sectors of the economy, but who, cognizant of the importance of sectoral interactions in the development process, and particularly agricultural development, wishes to embed his agricultural sector analysis in a broader macro-economic framework.

The model in its present form has general applicability particularly in medium-run policy analysis of 5 to 10 years. It is relatively simple, although dynamic, and uses data available for many countries (e.g., input-output tables, income elasticities). Moreover, it enables most of the important interactions between the agricultural sectors and the nonagricultural sectors to be explored, including the backward and forward linkages of agriculture, the induced consumption and investment effects resulting from changes in agricultural incomes, and the impact on food supply and demand of changes in migration out of agriculture. However, further research is needed to include a capital market and the supply side of the nonagricultural sectors in general, although this should not be at the expense of the flexibility and simplicity of the present model.

When applied to Nigeria, the macro-economic model is able to simulate major trends in the Nigerian economy from 1950–1967 with reasonable accuracy. Following 1967, the model provides predictions of macro-economic variables for use in an agricultural sector analysis, particularly the demand for food by the nonagricultural population for alternative agricultural strategies. Most importantly, by interacting with an agricultural sector simulation model, some valuable insights were provided into the macro-economic implications of alternative export and food promotion strategies in Nigeria. Finally, although the results presented in this paper emphasized conventional macro-economic measures of performance (i.e., *GDP*, foreign exchange) the authors have, by an industrial breakdown of the economy into large-scale and small-scale sectors, provided some insights into the relative effects of agricultural strategies on these sectors. This industrial breakdown and the endogenous specification of migration can be used to evaluate agricultural policies with respect to employment and income distribution variables of current concern to policy makers.

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# Farm Size, Rural Community Income, and Consumer Welfare*

EARL O. HEADY AND STEVEN T. SONKA

**Decline in the number of farms and the resulting increase in average farm size has been a persistent feature of the change occurring in American agriculture throughout the last three decades. Different farm-size assumptions are examined and their effect on certain key farm and nonfarm variables estimated. None of the alternatives analyzed provides benefits for all groups considered, and policies which may favor any one of these scenarios involve trade-offs between the variables discussed.**

*Key words:* **linear programming model; farm-size alternatives; net farm income; consumer food costs; farm prices; farm labor and capital usage; number of commercial farms; off-farm income generation.**

AMERICAN AGRICULTURE has been under some form of structural change since 1920. The number of farms and the work force of agriculture reached their peak about that time and, except for the 1930's depression, have been in a continuous downward trend for the last several decades. The trend toward fewer farms and a reduced work force was accentuated, of course, as postwar prosperity and technological improvements provided capital and scale economies favoring larger farms in all producing regions of the country.

## Farm Structure and Rural Community Welfare

These changes in the structure of farms were accompanied by shifts in the supply functions of agricultural commodities. Since markets were restrained by low domestic demand elasticities and a complex of institutional and economic restraints on exports, greater supply capacity brought actual or potential reductions in total revenue and net farm income to the agricultural sector. In attempts to ward off inequitable distributions wherein commercial agriculture sacrificed in income and the consuming sector gained in lowered real food prices, American society invested upwards of $70 billion on direct and indirect programs to increase farm income through supply control, commodity storage and loans, price supports, and international food aid. While massive programs were activated to help insure that commercial agriculture at large did not sacrifice from its structural transformation to fewer and larger farms, reduced work force and increased supply capacity, little attention was devoted to other large population groups whose economic opportunity and welfare were eroded through this same structural transformation. Consequently, the nonfarm sector of rural areas bore the major costs of this structural change as reductions in farm population and work force lessened employment opportunities, capital values, and social viability of the nation's typical rural communities.

## Objectives and Approach

The nation now has come to understand that the nonfarm sector of rural communities has borne the great cost of the structural evolution of the farm sector. Meager programs were initiated in the 1950's, and extended somewhat in the 1960's, aimed at relieving problems of underemployment, low incomes, and eroding social viability of rural communities. Perhaps spurred by apparent social and environmental diseconomies of large cities, the nation finally passed formal legislation giving recognition to the plight of rural communities. The Rural Development Act of 1972 is an explicit attempt of the public to concern itself with the inequities falling on the nonfarm sector of rural communities as farms become fewer and larger and as the direction of the nation's economic growth continues to move toward existing population centers [11]. Under Title V, Rural Development and Small Farm Research and Education, the Act suggests that improving or maintaining the position of small farms might contribute to the opportunities of rural America. This study attempts to quantify the interrelationships of welfare of rural com-

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munities and number and size of farms, which the Act implies. Analysis centers on this question: What would be the effect on major economic groups, including rural nonfarm and other sectors closely linked with agriculture, if the nation's agriculture were composed of farms of different sizes? The impacts on farm commodity prices, the interregional distribution of production, net farm income of the agricultural sector, net farm income per commercial farm, number of farms, labor used on farms, income generated in the rural nonfarm and agribusiness sectors associated with agriculture, and consumer food costs are evaluated and presented at regional and national levels.

Given the low price elasticities of demand for food commodities and the potential that lower rates of resource transformation on small farms would restrain supply, it is logical that if agriculture were made up of small farms, net income to the farm sector should be higher and consumer food costs should be greater. A system of small farms might also generate greater employment and income in rural areas because it implies a greater number of farm families and larger quantity of inputs to produce a given output. For the same reasons, an industry of large farms implies opposite outcomes. Various studies indicate that commercial farm policies of the last two decades were oriented to large commercial farms and generally brought gains to this group and to the general consumer sector at a relative sacrifice to hired farm labor, small farms, and the nonfarm rural community [6, 8].

While all facets of the relationships between farm-size structure and the welfare of different groups in the nation are not unraveled, the objective is to provide some initial estimates of trade-offs involved as a particular structure might prevail or be encouraged through public programs. Quantities such as these, placed in juxtaposition with weights which society attaches to various outcomes or variables relating to various economic groups, can then provide a basis for policy selection.

To measure these trade-offs and evaluate the impacts mentioned above, farms are restrained to three discrete sizes and generate the above quantities if the industry is composed of each. Commercial farming is represented by a "typical farm situation" wherein different sizes would prevail in terms of present trends in the farm-size distribution. For purposes of identification, farm-size alternatives are designated as: the Small Farm Alternative, the Medium Size Alternative, the Large Farm Alternative, and the Typical Farm Alternative. In implementing the study, farm inputs and outputs are first estimated by means of an interregional linear programming model. Input-output matrices are then estimated by regions and applied to indicate secondary income impacts. All estimates are projected for the year 1980.

## Methodology

The national linear programming model incorporates an interregional comparative advantage analysis, a transportation submodel, and an input-output submodel, and requires fulfillment of consumer demands in 31 market or consuming regions. Due to space limitations, details of the model are not presented here. With adaptations for time trends in technology, price indices, and demand, the basic model is essentially that outlined in Heady and Skold [1]. A more detailed discussion of this updated model can be found in [2, 5]. Commodity supplies are generated endogenously in each of 150 rural or agricultural areas shown in Figure 1, and land in each of these areas serves as an internal restraint on supply of crop commodities. The model minimizes the cost of producing the crop commodities in the 150 agricultural areas and transporting them among the 31 consuming regions but requires factor costs be covered for all commodities in each region. Supplies of crops included in the analysis are determined endogenously in the model while demands are estimated exogenously.

The study refers to the contiguous states of the U. S. and includes winter and spring wheat, all feed grains, soybeans, and cotton as endogenous commodities.[1] It also includes all forages and livestock products as fixed bounds. Both the linear programming model and the secondary impact variables used relate to various regional concepts. The 150 producing areas follow county boundaries and represent homogeneous areas of farm commodity production. Technical coefficients for each commodity by each farm size were computed separately for each of the 150 areas, and the model's objective function was optimized over these areas and the transportation network. Production patterns and resource use,

[1] The large "white" areas in Figure 1 are not included in the programming model. However, the 150 producing areas included account for production of 98 percent of the harvested acreage of the endogenous commodities. Production from the non-included areas is assumed equal to their 1969 production and is handled exogenously in the model.

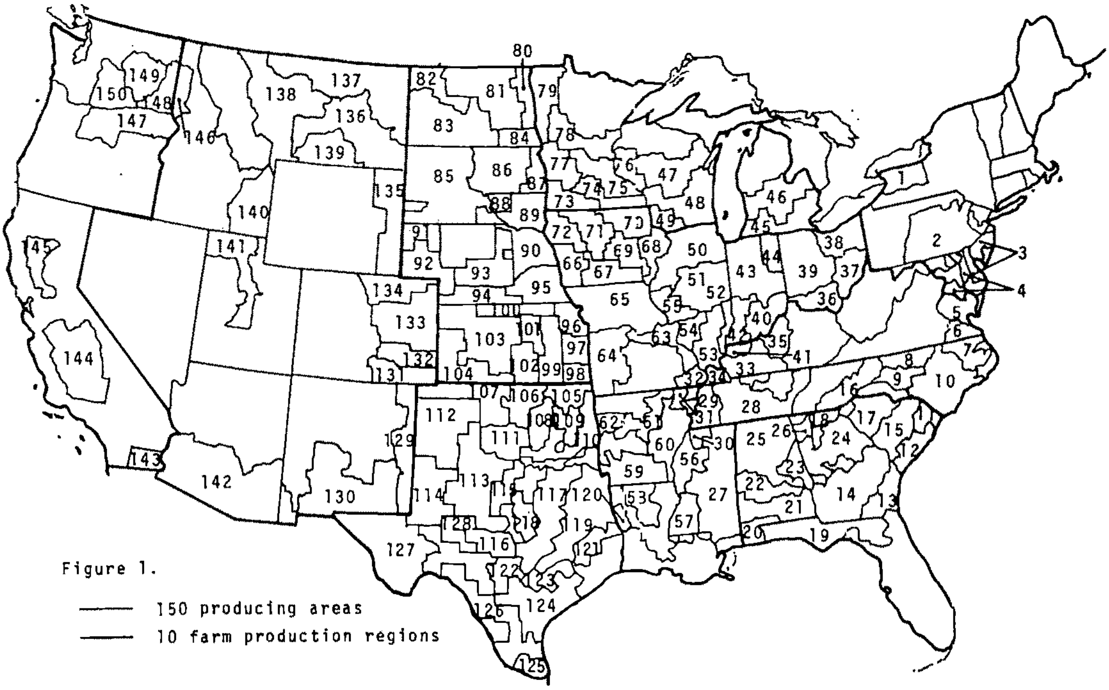


Figure 1.

computed for each rural area in the model solutions, are aggregated to production region levels in this report. Separate demand areas for winter and spring wheat, feed grains and oilmeals are defined by 31 consuming regions which follow state boundaries and encompass the continental United States. Cotton lint demand is determined on a national basis.

## Secondary income impact

One goal of this study is estimation of the potential effects of each farm-size alternative on income generated in agriculturally-related communities and industries. These off-farm impacts of agricultural production are important to a large segment of the nation since over one-fourth of the nation's population resides in nonmetropolitan areas and does not consist of farmers. But nonfarm people are closely related to the farming industry. Many work in industries which directly serve agriculture by supplying inputs to farmers, processing farm outputs, or supplying consumer goods and services. Other rural inhabitants work in nonagricultural industries which locate in agricultural communities and also have an interest in the future structure of farming. They consume many of the same services that farm operators and their families use. For example, schools, churches, and local governmental services which nonfarm industries and their employees demand and support also derive much of their support from farmers and the farming industry. Changes in the structure and viability of the farming industry, then, are reflected in the quality and quantity of services available in the community and affect all residents of rural America.

Hence, to measure secondary impacts, multipliers are used which relate output of each endogenous crop to income generated in agriculturally-related communities and industries. These multipliers are based on regional input-output matrices of the agricultural and agriculturally-related sectors.[2] These income multipliers express the increase in the total income for each of the production regions and for the U. S. economy due to the production of an additional one dollar's worth of output in an individual farm sector of the model. (The sector of relevance is a specific farm commodity produced in a specific farm production region.) This increase in total income has three components: (a) the income received by producers from an additional one dollar's worth of farm output; (b) the income resulting from the increased activity of agribusiness firms (through increased sales of productive inputs to farmers and the additional sales of industries that process farm products); and (c) the income resulting from increased sales of consumer goods to farmers and workers in agribusiness industries and rural com-

[2] The regional input-output matrices used in developing these multipliers are reported by Schluter [4].

munities. Different technological coefficients or input mixes exist for each farm size and each producing area. Hence, the income multipliers were recalculated, using the same basic regional input-output model, to reflect the technology of each of the farm-size alternatives analyzed.

### Parameters estimated for farm sizes and commodities

Production coefficients used in the Small Farm Alternative represent the technology of commercial farms with gross farm sales of less than $10,000. This grouping corresponds to farms in economic classes IV and V of the Bureau of Census. Commercial farms in this category had a U. S. average size of 232 acres in 1969. Such farms would be considered too small to provide an adequate farm family income with farming as the sole income source. Forty-one percent of the farm operators in this category were employed in off-farm work for more than 100 days in 1969.

The production coefficients for the Medium Size Alternative represent the structure of commercial farms in economic classes II and III of the Bureau of Census. Farms in these classes have gross farm sales of more than $10,000 but less than $39,999. The average farm in this grouping was 520 acres in size and had gross farm sales of $20,597 in 1969. Viability of farms in this category cannot be determined by the absolute level of their gross sales alone. The location and type of farming involved greatly affects the net income of particular farm operators in this category. In the analysis, differing productive coefficients are calculated according to the agricultural or rural area in which farms of the three alternatives are located.

Production data for the Large Farm Alternative characterize farms in economic class I, farms with gross sales greater than $40,000. For the U. S., these farms average 1,603 acres and $113,552 in gross sales in 1969. Farm operators in this group are highly commercial and could depend entirely on farming operations for family incomes.

The Typical Farm Alternative, the cost structure and productive technology of farming if recent farm-size trends continue to 1980, is used as a base for comparison with the three other farm-size alternatives. The average farm size under this alternative would be similar to that for farms under the Medium Size Alternative. However, farms of each of the three farm-size categories (small, medium, and large) are incorporated within the Typical Farm Alternative. Under this alternative, 39 percent of the acreage in farms is represented by farms of the Large Farm category, 41 percent by farms of the Medium Size category, and 20 percent by farms of the Small Farm category in 1980.

In this study iterative procedures were used to equate total demand with total supply for the Typical Farm Alternative. These quantities were then held constant for the other farm-size alternatives. This procedure was used in order that the mix of goods purchased by consumers would be fixed among alternatives and consumer expenditures for food would be standardized by commodity mix. While accomplishing this goal, the procedure tends to underestimate slightly the total production for situations with larger farms.

Although a large amount of quantitative work and modeling went into the study and is itself interesting, emphasis in this paper is on the results under projected alternatives in farm size. While resource use, commodity supplies, prices, and related data were computed for 150 agricultural areas, the data were summarized into aggregates for the 10 production regions of the U. S. indicated in bold outline in Figure 1. The input-output matrices, upon which the income multipliers are based, were also computed for these 10 production regions. Input-output matrices and multipliers for each of the 150 production regions in Figure 1 would have been preferable, but time and funds did not allow their derivation.

## Economic Impacts

Using projected 1980 coefficients for each farm size, farm employment in most of the 10 production regions would be greater under small farms than under large farms (Tables 1 and 2). However, since the national allocation of production differs among farm-size alternatives and because different output and input mixes are implied by areas for them, impacts on labor employment and capital use do vary among the 10 production regions. Regionally, labor and capital usage generally follows the pattern exhibited at the national level. Hours of labor required and the value of capital expenditures are generally highest under the Small Farm Alternative and lowest under the Large Farm Alternative. Exceptions are in the Appalachian and Southeast regions which devote more land to crops (especially to cotton in the latter region) under the Large Farm Alternative than under

Table 1. Hours of labor required for endogenous crops under the size alternatives for the U. S. and 10 farm production regions

| Region | Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
|---|---|---|---|---|
| | 1980 estimated labor requirements | | | |
| | Thousand hours | | | |
| United States | 1,213,394 | 1,517,108 | 1,199,232 | 1,093,121 |
| Northeast | 31,190 | 35,928 | 34,574 | 31,009 |
| Corn Belt | 458,844 | 576,629 | 436,054 | 410,565 |
| Lake States | 137,070 | 161,683 | 135,928 | 125,432 |
| Appalachian | 40,378 | 39,478 | 19,826 | 39,822 |
| Southeast | 18,142 | 19,733 | 13,736 | 21,288 |
| Delta States | 70,626 | 73,219 | 44,404 | 35,146 |
| Southern Plains | 151,727 | 237,552 | 207,896 | 208,869 |
| Northern Plains | 171,088 | 224,258 | 188,536 | 144,077 |
| Mountain | 76,040 | 77,830 | 62,991 | 58,051 |
| Pacific | 58,280 | 70,798 | 55,285 | 18,862 |

the other three size alternatives. In the Pacific region where cotton production is reduced under the Large Farm Alternative, labor and capital usage are less under this alternative than under other farm sizes. Hours of labor required by the Large Farm Alternative are 66 percent less and capital expenditures are 43 percent less than under the Medium Size Alternative.

The national capital-labor ratio would also vary among size alternatives. The Small Farm Alternative, the most labor intensive of the four, uses 39 percent more labor but only 29 percent more capital than the Large Farm Alternative (Table 2). The national capital requirement under the Typical Farm Alternative (with farms of three size categories) is 8 percent lower than under the Medium Size Alternative (farms of only the middle size category) and thus indicates somewhat greater capital intensity for the latter situation. These data indicate that farm size has important implications for economic opportunity of nonfarm sectors in rural communities.

## Prices and income

The linear programming model generates farm prices under each farm-size alternative. Table 3 presents these national prices with 1970 comparisons. (All prices were converted to 1970 dollar values.) Under the Typical Farm Alternative, wheat and cotton prices were near 1970 levels. However, feed grains and soybean prices are markedly lower than in 1970. For feed grains, this difference is partly due to the impact of corn blight in 1970. Since soybeans are produced on land best suited for them under the Typical Farm Alternative, production costs are lower than in 1970 resulting in a lower farm price than in 1970.

Under the Medium Size Alternative, farm

Table 2. Value of purchased inputs for endogenous crops under the size alternatives for the U. S. and 10 farm production regions

| Region | Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
|---|---|---|---|---|
| | 1980 estimated value of inputs purchased | | | |
| | Thousand dollars | | | |
| United States | 9,758,003 | 11,962,065 | 10,588,937 | 9,277,901 |
| Northeast | 335,006 | 364,037 | 337,336 | 270,654 |
| Corn Belt | 4,109,313 | 4,473,875 | 4,044,743 | 3,672,911 |
| Lake States | 1,045,865 | 1,180,215 | 1,002,105 | 870,239 |
| Appalachian | 315,252 | 364,197 | 268,949 | 316,946 |
| Southeast | 269,562 | 316,985 | 254,665 | 323,794 |
| Delta States | 532,240 | 581,593 | 482,232 | 386,249 |
| Southern Plains | 1,197,679 | 1,518,603 | 1,334,751 | 1,167,331 |
| Northern Plains | 1,788,640 | 2,025,595 | 1,847,191 | 1,515,351 |
| Mountain | 607,042 | 555,706 | 536,343 | 482,821 |
| Pacific | 498,582 | 581,259 | 480,622 | 271,605 |

Table 3. U. S. farm prices for the size alternatives with 1970 prices for comparison

| Crop | Unit | 1970 Prices[a] | 1980 estimated prices[b] Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
|---|---|---|---|---|---|---|
| Wheat | dol./bu. | 1.33 | 1.36 | 1.61 | 1.36 | 1.23 |
| Feed grains | | | | | | |
| Corn equivalent | dol./bu. | 1.33 | 1.11 | 1.28 | 1.10 | .95 |
| Soybeans | dol./bu. | 2.85 | 2.33 | 2.77 | 2.26 | 1.91 |
| Cotton | cents/lb. | .22 | .22 | .24 | .21 | .19 |

[a] Source: [7].
[b] All prices for 1980 are measured in 1970 dollars and do not include inflation to 1980.

prices nearly equal their level under the Typical Farm Alternative. However, they are considerably lower under the Large Farm Alternative than under the Medium Size Alternative. Under the Small Farm Alternative, farm prices are considerably higher than under the other three alternatives.

Price differences between the Medium and Large Farm Alternatives for feed grains and for cotton nearly equal the differences estimated between the Medium and Small Farm Alternatives. However, for wheat the per bushel price differential is 13 cents between the Large and Medium Farm Alternatives but is 25 cents between the Medium and Small Farm Alternatives. Similarly, the per bushel price differential for soybeans between the Large and Medium Farm Alternatives is 35 cents but is 51 cents between the Medium and Small Farm Alternatives. Lower prices are generated under the situations with large farms because their lower production costs give rise to lower supply prices. In general, then, price is expected to decrease as farm size is increased.

Even though government farm program payments are not included in 1980, total net returns to the farming industry exceed actual 1970 returns under all size alternatives (Table 4). The highest net returns occur under the Small Farm Alternative because of its higher farm product prices. Net returns under this alternative are $9.4 billion higher than under the Large Farm Alternative which has the lowest return of the four alternatives.

For each farm size alternative, Table 4 also includes the estimated number of commercial farms (those with gross sales over $2,500) in 1980. The Typical Farm Alternative requires

Table 4. U. S. total net farm income, net farm income per commercial farm, and related data under the size alternatives, with actual 1970 values for comparison

| | 1970[a] | 1980 estimated values Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
|---|---|---|---|---|---|
| | | | Million dollars[b] | | |
| Cash receipts from farm marketings | 49,231 | 58,221 | 67,946 | 57,867 | 50,429 |
| Production expenses[c] | 40,867 | 43,862 | 48,014 | 43,583 | 39,865 |
| Net receipts from farm marketings | 8,364 | 14,359 | 19,932 | 14,284 | 10,564 |
| Non-money income and inventory change[d] | 3,858 | 3,632 | 3,632 | 3,632 | 3,632 |
| Net returns from farming | 12,222 | 17,991 | 23,564 | 17,916 | 14,196 |
| Income from government sources[e] | 3,717 | 0 | 0 | 0 | 0 |
| Total net farm income | 15,939 | 17,991 | 23,564 | 17,916 | 14,196 |
| Number of commercial farms (thousands)[f] | 1,930 | 1,550 | 5,585 | 1,652 | 1,001 |
| Net farm income per commercial farm (dollars) | 8,258 | 11,607 | 4,219 | 10,845 | 14,182 |

[a] Source: [8].
[b] All dollar values are measured in 1970 dollars with no adjustment for inflation to 1980.
[c] For the equations used to estimate production expenses for the Typical Farm Alternative, see [3].
[d] Includes the value of home consumption and the rental value of farm dwellings.
[e] Includes ACP, Great Plains Conservation, Sugar Act, and Wool Act payments as well as payments under the Wheat, Feed Grains, and Cotton programs.
[f] Source: [10].

400,000 few commercial farms than existed in 1970. The smaller number is due to the larger average farm size represented by the Typical Farm Alternative. The average size is 613 acres under this alternative, compared to 383 acres in 1970. The Medium Size Alternative requires 102,000 more farms than the Typical Farm Alternative because of the smaller average size of the latter. The 5.6 million commercial farms of the Small Farm Alternative are considerably more than under the other alternatives.

Net income per commercial farm under the Large Farm Alternative is $14,182, which is $5,924 higher than the 1970 per farm net income. This relatively high net income per farm occurs under the Large Farm Alternative even though net income for the farming industry as a whole is lowest under this alternative. The average size under this alternative, 1,140 acres, is much greater than under the other alternatives, and induces higher per farm net income through lower unit costs, fewer farms, and greater sales per farm. Only slightly over a million commercial farms would be required under this alternative, 929,000 fewer than in 1970. Hence, greater net income per farm is attained at the expense of net income to the total farm sector. Or conversely, for the Small Farm Alternative, greater net income for the total farm industry comes at the expense of net income per farm which is estimated to be $4,219 under this alternative.

### Consumer food expenditures

Consumer food expenditures under each of the alternatives is expected to be considerably higher than actual 1970 expenditures due to population increases, higher family incomes, and increased per capita consumption of meat products by 1980. Consumer expenditures for food under the Small Farm Alternative are higher than under the other three alternatives. Estimated 1980 expenditures under this alternative are $5.5 billion greater than under the Typical or Medium Size Alternatives and almost $10 billion greater than under the Large Farm Alternative.

On a per capita basis, estimated 1980 food expenditures under all of the alternatives are significantly greater than 1970 actual expenditures, mainly due to increased expenditures on meat products and fruits and vegetables (Table 5). The Small Farm Alternative has a slightly higher per capita food expenditure than do the other size alternatives. Under this alternative, per capita food expenditures are $24 more than under the Medium or Typical Farm Alternatives and $43 greater than under the Large Farm Alternative.

The results presented here indicate that increased farm size causes a sacrifice in total net income to the farm sector, number of farms, and total farm employment. However, it is an advantage in income to farmers who operate the larger units and to consumers in lower food costs. These factors represent an important subset of the trade-offs facing the American public as policies are promoted to favor a particular size structure or as the forces of the market and technology carry farms to a larger size over time.

### Secondary or off-farm income generation

This section indicates how income generated in rural communities and agriculturally-related industries, as well as in agriculture, is affected by

**Table 5. U. S. total and per capita consumer food expenditures for the size alternatives, with 1970 expenditures for comparison**

| | Consumer food expenditures 1970[a] | 1980 estimated consumer food expenditures | | | |
|---|---|---|---|---|---|
| | | Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
| | | Total expenditures (million dollars)[b] | | | |
| Meat products | 31,351 | 49,867 | 55,167 | 49,867 | 45,917 |
| Poultry and eggs | 8,620 | 7,789 | 8,052 | 7,789 | 7,526 |
| Dairy products | 16,341 | 15,075 | 15,075 | 15,075 | 15,075 |
| Other[c] | 49,568 | 77,888 | 77,888 | 77,888 | 77,888 |
| All products | 105,879 | 150,619 | 156,182 | 150,619 | 146,406 |
| | | Per capita costs (dollars) | | | |
| Per capita costs | 528 | 664 | 688 | 664 | 645 |

[a] Source: [9].
[b] All values for 1980 are measured in 1970 equivalent dollars with no adjustment for inflation to 1980.
[c] Includes bakery products, fruits and vegetables, miscellaneous items, and grain mill products.

each farm-size alternative. The amount of income generated outside of agriculture is affected by both (a) the acreages of crops and levels of production and (b) the level of farm income associated with each of the alternatives considered. Secondary income generated under each alternative has been expressed as an index value to allow a direct comparison among the farm-size alternatives.

Nationally, the income index value estimated under the Small Farm Alternative, 116.5, is considerably higher than under the Typical Farm Alternative. This difference is due to the increased value of output and greater input requirements associated with the former alternative. Only in the Delta States is income generated under the Typical Farm Alternative greater than under the Small Farm Alternative. This region has more acres in production under the Typical Farm Alternative than under the other three alternatives and thus generates more off-farm income. The off-farm income index values in the Northeast and the Mountain regions are only slightly higher under the Small Farm Alternative than under the Typical Farm Alternative while the other seven regions have index values at least 9 percent greater under the Small Farm Alternative (Table 6). These seven regions have as many or more acres in production under this alternative and benefit from the higher farm prices of the Small Farm Alternative. The largest increases under the Small Farm Alternative are in the Southern Plains region, 38 percent, and in the Northern Plains region, 21.2 percent. Both of these regions produce more feed grains and less wheat under the Small Farm Alternative than under the Typical Farm Alternative. Cotton production in the Southern Plains region is also significantly higher under the Small Farm Alternative.

Due to lower farm prices, fewer farms, and less labor under the Large Farm Alternative, the national nonfarm income index value is 15.3 percent lower under this alternative than under the Typical Farm Alternative and 27.3 percent lower than under the Small Farm Alternative. Index values in the Northeast, Corn Belt, Lake States, Northern Plains, and Mountain regions decrease by nearly the same amount as the national figure under the Large Farm Alternative. These regions have nearly the same number of acres in production under the Large Farm Alternative as under the Typical Farm Alternative, but the lower prices and reduced labor and capital inputs act to depress the amount of off-farm income generated in these regions. The index value in the Delta States region is almost 40 percent lower under the Large Farm Alternative than under the Typical Farm Alternative while the largest difference is for the Pacific region, an estimated 60 percent. Cotton production in both regions is much less under the Large Farm Alternative than under the Typical Farm Alternative. Cotton acreage in the Pacific region would be shifted to grains under the Large Farm Alternative which would generate less off-farm income for this region. As compared to the Typical Farm Alternative, the Southeast, Appalachian, and Southern Plains regions would have higher income index values under the Large Farm Alternative due to increased cotton production in the Southeast and increased wheat and feed grains production in the latter two regions.

Reduced off-farm income characterizes the economic and social difficulties which have come

**Table 6. Indices comparing off-farm income generated in the U. S. and 10 farm production regions under the size alternatives**

| Region | 1980 estimated index values | | | |
|---|---|---|---|---|
| | Typical Farm Alternative | Small Farm Alternative | Medium Size Alternative | Large Farm Alternative |
| United States | 100.0 | 116.5 | 98.6 | 84.7 |
| Northeast | 100.0 | 101.3 | 98.9 | 87.8 |
| Corn Belt | 100.0 | 115.7 | 97.0 | 83.6 |
| Lake States | 100.0 | 117.9 | 97.3 | 83.7 |
| Appalachian | 100.0 | 114.2 | 79.2 | 113.7 |
| Southeast | 100.0 | 109.5 | 88.0 | 132.8 |
| Delta States | 100.0 | 94.1 | 71.5 | 60.3 |
| Southern Plains | 100.0 | 138.0 | 122.4 | 115.0 |
| Northern Plains | 100.0 | 121.2 | 104.6 | 83.7 |
| Mountain | 100.0 | 101.2 | 83.7 | 79.2 |
| Pacific | 100.0 | 109.5 | 99.0 | 39.5 |

to prevail in typical rural communities as the agricultural structure moves from small farms to larger farms. While large farms can produce with lower costs and can supply markets at lower prices, they use fewer total farm inputs including labor. Thus, fewer service firms can exist. The smaller farm work force also would result in fewer purchases of consumer goods and services from local merchants. As Table 6 shows, these elements of nonfarm income and employment generation are generally larger under the Small Farm Alternative and generally lower under the Large Farm Alternative. With production concentrating in regions of greatest advantage under the structure of the programming model, the largest difference in nonfarm income estimated for 1980 is for the Pacific region. Here, nonfarm income generated under the Large Farm Alternative is 63.8 percent less than under the Small Farm Alternative.

## General Implications

This analysis was made as an examination of general alternatives in rural community income generation and welfare in relation to farm-size alternatives. The study provides quantitative insights of trade-offs among consumers, large farmers, small farmers, and rural community or agriculturally-related sectors in relation to particular farm-size structures for American agriculture. The results show that a structure of small farms would indeed lead to greater income generation in rural communities. This additional income, for the agricultural sector as a whole and for other parts of the rural community, would come at a relatively modest cost to the consumer in higher food costs. It would, however, impose a greater burden on the families operating these small farms, and their incomes would be at levels now characterizing poverty unless special means were used to involve them in part-time off-farm work. For several reasons, a goal or effort on behalf of a medium farm size would be more compatible with adequate farm family incomes, generation of nonfarm rural income, and reasonable consumer food costs.

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# Optimal Agricultural Pest Management with Increasing Pest Resistance*

D. Hueth and U. Regev

**The effect of increasing pest resistance to insecticides on the optimal control of a pest population is investigated by constructing a single-pest, single-crop management model and analyzing the resulting optimality conditions. Use of insecticides under these conditions results in both monetary costs and user costs. It is suggested that growers do not generally consider these user costs and therefore do not obtain maximum profits. The dynamic formulation of the model results in an extension of the literature dealing with the "economic-threshold," which under reasonable conditions is shown to be increasing during the course of the season.**

*Key words:* **pest resistance; user-costs; economic threshold.**

The major purpose of this paper is to incorporate the concept of pest resistance into pest management models and to illustrate the close relationship existing between the "economics of pest resistance" and the "economics of exhaustible resources." In addition, some clarification and additional results on the concept of the "economic threshold" are provided.

According to R. F. Smith [12, p. 104], ". . . we must assume that any anthropod exposed to intensive pesticide pressure will develop insecticide resistance"; thus, any realistic model of optimal pest management must recognize this phenomenon. With the exception of an unpublished paper by C. Robert Taylor and J. C. Headley [13], none of the models presently available in the literature take resistance into consideration.[1]

Economists have long recognized that pest management involves the management of a detrimental renewable resource—the pest population. What has not been well understood is that, for a particular chemical control, pest management also involves the management of an exhaustible resource. This characteristic of pest management was first recognized and conveyed by Carlson and Castle [4] who introduced the term "biological capital" to describe ". . . our current stock of pesticide material and use recommendations . . . that accumulates and depreciates when investments are made and services provided change." Since neither materials nor use recommendations are "biological" in nature, their definition is somewhat misleading. However, from their subsequent discussion, it is clear that what the authors had in mind is the *effectiveness* of the stock of materials, which depends on the pest species, rather than the *quantity*, which does not. In this paper biological capital is viewed as the total susceptibility of a particular species to currently developed pesticides, susceptibility being defined as the negative of resistance. It is, then, a natural resource stock subject to management in a manner analogous to resource stocks in other extractive industries, extraction in this case being the application of pesticides. Thus, the optimal application of pesticides implies conjunctive management of both the pest and its associated stock of susceptibility.

The problem of optimal insect pest management in agricultural production has attracted the attention of only a few economists. The most notable works to date are the papers of Headley [7] and Hall and Norgaard [6]. Both of these papers are attempts to provide a precise definition of the economic threshold—a term developed by entomologists to denote the pest population level at which control measures should be initiated—by constructing optimal pest control models. As Hall and Norgaard point out, the Headley model is essentially a static model and thus provides no information on the opti-

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[1] For a survey of deterministic pest management models, as well as demonstrations of application of dynamic programming to pest management, see Shoemaker [11].

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mal timing of applications during the season. The Hall and Norgaard model corrects this deficiency but assumes there is a single optimal time of application which is determined simultaneously with the optimal dosage. For many crops it is likely that the optimal policy of pesticide use will imply multiple applications during the season, especially where nonmaterial application costs are small or zero as assumed in the Hall and Norgaard paper. The model presented in the following section assumes that pesticides may be applied at any one of an arbitrarily large number of times, allowing for consideration of the dynamic properties of the economic threshold.

## The Model

This section presents a single-pest, single-crop management model for cases where the pest is developing increasing resistance as a result of pesticide applications.[2] The model is highly simplified from a biological standpoint for the dual purposes of emphasizing the economic considerations and increasing the scope of applicability. The decision-maker may be viewed as either a central decision-maker for a region that has largely a monoculture with one key pest or a grower with an appropriable pest population. The word "appropriable" is used here in the same context as it has been used in conjunction with the management of other biological resources; see, especially, Quirk and Smith [9, pp. 3–32]. For insect populations it simply means the authors assume there is no emigration or immigration.

The planning horizon is one growing season; however, it is recognized that pest management decisions made during one season are not generally independent of future seasons. The problem of multiseasonal optimization is simplified by assuming in the ensuing model that the benefit function includes as arguments the terminal stock of pest susceptibility and the terminal pest population to reflect the present value of future profits and costs, respectively, of carrying stocks of these variables forward in time.

[2] The Taylor-Headley paper [13], which came to our attention while this manuscript was in progress, suggests a dynamic programming model. It views the pest population as being composed of a number of genotypes with various levels of susceptibility; assuming random mating, pesticide applications select against the more susceptible genotypes. The paper does not, however, provide an economic analysis of the optimal pesticide policy, nor does it concern itself with the properties of the "economic threshold."

The current growing season is partitioned into $t'$ periods. In some applications these periods may simply be days or weeks of the season; in others, the periods may be chosen to coincide with various stages of the insects' life cycle or with stages of plant growth. Let $t_0$ be the beginning of the initial period and $t'$ be the end of the last period or the time of harvest. The state variables of the system at the beginning of any period $t$ are

$x_{1t} \triangleq$ the measure of potential plant product,

$x_{2t} \triangleq$ the pest population density,

and

$x_{3t} \triangleq$ an index of stock of pest susceptibility.

At each $t$, the decision-maker has control over

$u_{1t} \triangleq$ a nonpest control input,

and

$u_{2t} \triangleq$ a chemical pest control input,

each of which is nonnegative.

It is assumed that crop yield is monotonically increasing in $x_{1t}$—the measure of potential plant product at any $t$. In addition, the pest population is assumed to affect directly the measure of potential plant product. An example of where these conditions are reasonable is provided by alfalfa with $x_{1t}$ defined as pounds of dry matter. In cases where the pest damage is measurable by some attribute of the plant not directly related to crop yield, it is necessary to use more than one state variable and the functional relationships to describe the potential yield of the plant at any $t$. Barr [1] used plant weight, leaf surface area, and weight and surface area of the grain heads to describe the state of the plant in a model for cereal leaf beetle control. In some cases, such as the boll weevil in cotton, the pest directly affects fruit of the plant. This would require a modification of equation (3) of the following model to reflect the fact that the rate of change in the stock of potential plant product is independent of stock of the same.

In describing the effect of chemical input on the pest population, it is assumed, as is frequently done in entomological research, that insect mortality from insecticides is independent of the size of the pest population. The percentage reduction in $x_{2t}$ for various levels of $x_{3t}$, $u_{2t}$, is given by $h(x_{3t}, u_{2t})$ which is assumed to have the following properties: $h(x_{3t}, 0) = h(0,$

$u_{2t}) = 0$, $h_{u_2} > 0$, $h_{u_2u_2} > 0$ for low rates of application, and $h_{u_2u_2} < 0$ for high rates of application.[3] The index of the stock of pest susceptibility ($x_{3t}$) is a parameter for a particular dosage response curve. As susceptibility increases, the dosage response curve shifts upward ($h_{x_3} > 0$) as indicated in Figure 1.[4]

Assuming that $u_{2t}$ is applied at the beginning of period $[t, t+1]$ and is immediately effective, the pest population after application is given by $z_t = x_{2t} - h(x_{3t}, u_{2t})\, x_{2t}$. Letting $g(z_t, t)$ be the natural growth of pest population during the period, the pest population at $t+1$ is given by

$$(1) \quad x_{2,t+1} = z_t + g(z_t, t) = x_{2t} + f^2(x_{2t}, x_{3t}, u_{2t}, t)$$

where $f^2$ represents the net change in the pest population from $t$ to $t+1$. Using the assumptions on $h$ above and assuming $g_z > 0$, $f^2$ has the following properties:

$$(2) \qquad f_{u_2}{}^2 \leqslant 0 \quad f_{x_2}{}^2 \geqslant 0 \quad f_{x_3}{}^2 \leqslant 0.$$

Figure 2 illustrates the process for the pest population model.

The pest population model is now coupled with the plant growth model. In the absence of

[3] For any function $\psi(x, u)$, $\psi_x = \partial\psi/\partial x$, $\psi_u = \partial\psi/\partial u$, and $\psi_{ux} = \partial^2\psi/\partial_u\partial_x$. Where the meaning is clear, time subscripts have been dropped, e.g., $h_{u_{2t}} = h_{u_2}$.

[4] Entomologists have measured increasing resistance by the percentage increases in the median lethal dose. In a similar manner we propose as a measure of the index of pest susceptibility the mortality rate of the pest population for an arbitrarily selected level of chemical application.

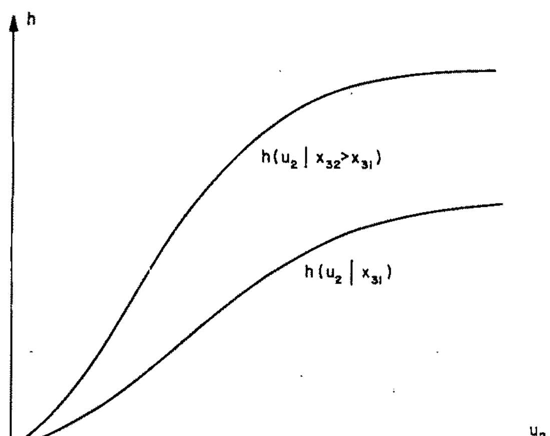


**Figure 1. Typical dosage response curves for two levels of pest susceptibility**

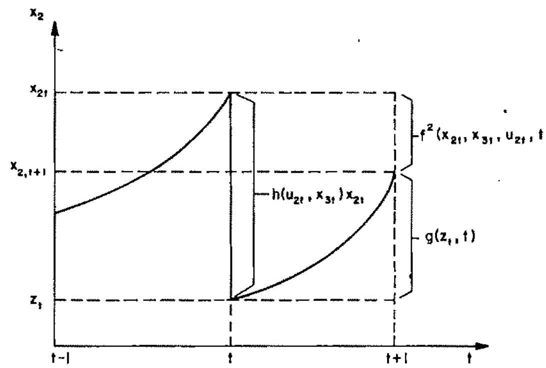


**Figure 2. An illustration of the pest population process over two time periods**

a pest population, increase in plant size from $t$ to $t+1$ is given by a concave-increasing function $q(x_{1t}, u_{1t}, t)$. In general plant growth is diminished during the period as the pest population increases; but, since pest population in the $t$th period is a function of $z_t$, a damage function $m(z_t, t)$ may be composed to represent this reduction. The argument $t$ enters explicitly in $m(\cdot)$ since the damage may change over time. It is assumed that $m(\cdot)$ is a convex-increasing function in $z_t$. Plant size at $t+1$ is given by

$$(3) \quad x_{1,t+1} = x_{1t} + q(x_{1t}, u_{1t}, t) - m(z_t, t) = x_{1t} + f^1(x_{1t}, x_{2t}, x_{3t}, u_{1t}, u_{2t}, t)$$

where $f^1$ is the net increase in plant size from $t$ to $t+1$, and

$$(4) \quad f_{x_1}{}^1 \geqslant 0 \quad f_{u_1}{}^1 \geqslant 0 \quad f_{x_2}{}^1 \leqslant 0 \quad f_{x_3}{}^1 \geqslant 0 \quad f_{u_2}{}^1 \geqslant 0.$$

As mentioned above, the stock of pest susceptibility may be viewed as an exhaustible natural resource. The depletion process of this resource is described by

$$(5) \qquad x_{3,t+1} = x_{3t} - f^3(u_{2t}, x_{3t})$$

where $f^3$ has the following properties:

$$(6) \quad f_{u_2}{}^3 \geqslant 0, f_{x_3}{}^3 \leqslant 0, f^3(0, x_{3t}) = f^3(u_{2t}, 0) = 0.$$

By (6), as pesticides are used at any $t$, the stock of susceptibility is reduced; but considerable uncertainty exists concerning whether this stock decreases at an increasing or decreasing rate ($f_{u_2u_2}{}^3 \lesseqgtr 0$). If susceptibility decreases at a decreasing rate ($f_{u_2u_2}{}^3 < 0$), a single large application during the season results in a terminal stock of susceptibility larger than the terminal stock resulting from multiple applications that sum to the same total amount over the season.

At a recent meeting of the Environmental Studies Board of the National Academy of Science, representatives of the chemical industry argued that this is indeed the case. However, other biologists have argued that infrequent large applications result in a faster rate of depletion than frequent small applications, which would imply in this model $f_{u_{2t}u_{2t}}{}^3 > 0$.

It is also assumed that increases in the stock of vulnerability reduce the rate of vulnerability depletion ($f_{x_3}{}^3 \leqslant 0$). This assumption is in accordance with the frequently observed field phenomenon that, when a pest is partially resistant to a particular compound, resistance develops more rapidly than when the pest has little or no prior resistance.

Given any policy of pest and nonpest control inputs over the season, the three components of the model developed thus far (plant, pest, and susceptibility) determine unique time paths of the state and control variables of the model and unique terminal values of plant size, pest size, and the stock of pest susceptibility. The objective function is now introduced, and the optimization problem of the decision-maker is stated.

For the season under consideration, a concave benefit function $B_1(x_{1t'})$ and a convex cost function $c(u_{1t}, u_{2t})$ are assumed. Expected future net profits associated with carrying forward terminal stocks of the pest population at a particular level of susceptibility are summarized in a concave function $B_2(x_{2t'}, x_{3t'})$ which is assumed to have the properties $\partial B_2/\partial x_{2t'} < 0, \partial B_2/\partial x_{3t'} > 0$. Then the optimization problem is

$$\max_{u_{1t}u_{2t}} B_1(x_{1t'}) + B_2(x_{2t'}, x_{3t'}) - \sum_{t=t_0}^{t'-1} c(u_{1t}, u_{2t})$$

subject to

(7)
$$x_{1,t+1} = x_{1t} + f^1(x_{1t}, x_{2t}, x_{3t}, u_{1t}, u_{2t}, t) \qquad t = 0, 1 \ldots t' - 1$$
$$x_{2,t+1} = x_{2t} + f^2(x_{2t}, x_{3t}, u_{2t}, t) \qquad t = 0, 1 \ldots t' - 1$$
$$x_{3,t+1} = x_{3t} - f^3(x_{3t}, u_{2t}) \qquad t = 0, 1 \ldots t' - 1$$
$$u_{1t}, u_{2t} \geqslant 0 \quad x_{it_0} = x_i^0 \qquad i = 1, 2, 3.$$

This is a standard discrete time optimal control problem. If the constraint qualification is satisfied, multipliers $\lambda_i^t$ may be introduced for each of the transition functions (7), and a Hamiltonian function

$$(8) \quad H = -c(u_{1t}, u_{2t}) + \lambda_1^{t+1} f^1(x_{1t}, x_{2t}, x_{3t}, u_{1t}, u_{2t}, t) + \lambda_2^{t+1} f^2(x_{2t}, x_{3t}, u_{2t}, t) - \lambda_3^{t+1} f^3(x_{3t}, u_{2t})$$

may be formed which is to be maximized with respect to $u_{it}$ at each $t$ subject to $u_{it} \geqslant 0$.[5]

Then,

$$(9) \quad \frac{\partial H}{\partial u_{1t}} = -c_{u_{1t}} + \lambda_1^{t+1} f_{u_{1t}}{}^1 \leqslant 0, \qquad \frac{\partial H}{\partial u_{1t}} u_{1t} = 0, u_{1t} \geqslant 0$$

$$(10) \quad \frac{\partial H}{\partial u_{2t}} = -c_{u_{2t}} + \lambda_1^{t+1} f_{u_{2t}}{}^1 + \lambda_2^{t+1} f_{u_{2t}}{}^2 - \lambda_3^{t+1} f_{u_{2t}}{}^3 \leqslant 0, \qquad \frac{\partial H}{\partial u_{2t}} u_{2t} = 0, \quad u_{2t} \geqslant 0$$

must be satisfied for optimal choices of $u_{it}$ at any $t$.

Additional necessary conditions of interest are

$$(11) \quad \frac{\partial H}{\partial x_{1t}} = \lambda_1^t - \lambda_1^{t+1} = \lambda_1^{t+1} f_{x_{1t}}{}^1$$

$$(12) \quad \frac{\partial H}{\partial x_{2t}} = \lambda_2^t - \lambda_2^{t+1} = \lambda_1^{t+1} f_{x_{2t}}{}^1 + \lambda_2^{t+1} f_{x_{2t}}{}^2$$

$$(13) \quad \frac{\partial H}{\partial x_{3t}} = \lambda_3^t - \lambda_3^{t+1} = \lambda_1^{t+1} f_{x_{3t}}{}^1 + \lambda_2^{t+1} f_{x_{3t}}{}^2 - \lambda_3^{t+1} f_{x_{3t}}{}^3$$

and the transversality conditions

$$(14) \quad \lambda_1^{t'} = \frac{\partial B_1}{\partial x_{1t'}} > 0, \qquad \lambda_2^{t'} = \frac{\partial B_2}{\partial x_{2t'}} < 0, \qquad \lambda_3^{t'} = \frac{\partial B_2}{\partial x_{3t'}} > 0.$$

The economic interpretation of these conditions will be clarified by the development of expressions for $\lambda_i^t$ at any $t$. Iterating (11) to (13) forward in time,

$$(15) \qquad \lambda_1^t = \lambda_1^{t'} \prod_{i=t}^{t'-1} (1 + f_{x_{1i}}{}^1)$$

[5] See, for example, Varaiya [14].

$$(16)\quad \lambda_2^t = \lambda_1^{t+1} f_{x_{2t}}^{\,1} + \sum_{i=t+1}^{t'-1} \lambda_1^{i+1} f_{x_{2i}}^{\,1} \prod_{s=t}^{i-1} (1 + f_{x_{2s}}^{\,2}) + \lambda_2^{t'} \prod_{s=t}^{t'-1} (1 + f_{x_{2s}}^{\,2})$$

$$(17)\quad \lambda_3^t = \lambda_1^{t+1} f_{x_{3t}}^{\,1} + \lambda_2^{t+1} f_{x_{3t}}^{\,2} + \sum_{i=t+1}^{t'-1} \lambda_1^{i+1} f_{x_{3i}}^{\,1} \prod_{s=t}^{i-1} (1 - f_{x_{3s}}^{\,3}) + \sum_{i=t+1}^{t'-1} \lambda_2^{i+1} f_{x_{3i}}^{\,2} \prod_{s=t}^{i-1} (1 - f_{x_{3s}}^{\,3}) + \lambda_3^{t'} \prod_{i=t}^{t'-1} (1 - f_{x_3}^{\,3_i}).$$

Noting that

$$(18)\quad f_{x_{kj}}^{\,i} = \frac{\partial x_{i,j+1}}{\partial x_{kj}}, \qquad i, k = 1, 2, 3 \quad i \neq k$$

$$\prod_{k=s}^{j} (1 - f_{x_{3k}}^{\,3}) = \frac{\partial x_{3,j+1}}{\partial x_{3s}}, \qquad j \geqslant s$$

and

$$(19)\quad \prod_{k=s}^{j} (1 + f_{x_{ik}}^{\,i}) = \frac{\partial x_{i,j+1}}{\partial x_{is}}, \qquad i = 1, 2 \quad j \geqslant s$$

and using equations (14) and (15), equation (17) may be written

$$(20)\qquad \lambda_1^t = \frac{\partial B_1}{\partial x_{1t'}} \frac{\partial x_{1t'}}{\partial x_{1t}} = \frac{\partial B_1}{\partial x_{1t}}$$

$$(21)\quad \lambda_2^t = \sum_{i=t}^{t'-1} \frac{\partial B_1}{\partial x_{1t'}} \frac{\partial x_{1t'}}{\partial x_{1,i+1}} \frac{\partial x_{1,i+1}}{\partial x_{2i}} \frac{\partial x_{2i}}{\partial x_{2t}} + \frac{\partial B_2}{\partial x_{2t'}} \frac{\partial x_{2t'}}{\partial x_{2t}} = \frac{\partial B_1}{\partial x_{2t}} + \frac{\partial B_2}{\partial x_{2t}}$$

$$(22)\quad \lambda_3^t = \sum_{i=t}^{t'-1} \frac{\partial B_1}{\partial x_{1t'}} \frac{\partial x_{1t'}}{\partial x_{3,i+1}} \frac{\partial x_{3,i+1}}{\partial x_{3i}} \frac{\partial x_{3i}}{\partial x_{3t}} + \sum_{i=t}^{t'-1} \frac{\partial B_2}{\partial x_{2t'}} \frac{\partial x_{2t'}}{\partial x_{3,i+1}} \frac{\partial x_{3,i+1}}{\partial x_{3i}} \frac{\partial x_{3i}}{\partial x_{3t}} + \frac{\partial B_2}{\partial x_{3t'}} \frac{\partial x_{3t'}}{\partial x_{3t}} = \frac{\partial B_1}{\partial x_{3t}} + \frac{\partial B_2}{\partial x_{3t}}.$$

The signs and time paths of the $\lambda_i^t$ are now investigated. From (15), it is clear that, since $f_{x_1}^{\,1} \geqslant 0$, $\lambda_1^t \geqslant 0 \;\forall\, t$. Using this result in (11), $\lambda_1^t - \lambda_1^{t+1} \geqslant 0 \;\forall\, t$. Thus, at the beginning of the season, $\lambda_1^t$ is positive and, during the season, it monotonically decreases to $\partial B_1/\partial x_{1t'}$. Recalling that $f_{x_2}^{\,1} \leqslant 0$ and $f_{x_2}^{\,2} \geqslant 0$, by (16) $\lambda_2^t \leqslant 0 \;\forall\, t$, and by (12) $\lambda_2^t - \lambda_2^{t+1} \leqslant 0 \;\forall\, t$. Thus, $\lambda_t^2$ monotonically increases during the season to $\partial B_2/\partial x_{2t'}$. Given $\lambda_1^t \geqslant 0$, $\lambda_2^t \leqslant 0$, $\lambda_3^{t'} > 0$, $f_{x_3}^{\,1} \geqslant 0$, $f_{x_3}^{\,2} \leqslant 0$, and $f_{x_3}^{\,3} \leqslant 0$, by (17) $\lambda_3^t \geqslant 0 \;\forall\, t$ which, by (13), implies $\lambda_3^t - \lambda_3^{t+1} \geqslant 0 \;\forall\, t$. Thus, $\lambda_3^t$ is nonincreasing during the season and terminates at $\partial B_2/\partial x_{3t'}$. Summarizing these results,

$$(23)\qquad \lambda_1^t \geqslant 0, \lambda_2^t \leqslant 0, \lambda_3^t \geqslant 0$$
$$\lambda_1^t - \lambda_1^{t+1} \geqslant 0, \lambda_2^t - \lambda_2^{t+1} \leqslant 0, \lambda_3^t - \lambda_3^{t+1} \geqslant 0.$$

## Economic Interpretation

This discussion begins with an interpretation of $\lambda_i^t$. By (20), $\lambda_1^t$ is interpreted as the marginal revenue resulting from an incremental change in potential plant product ($x_{1t}$). Assuming $f_{x_1}^{\,1} > 0$, increases in $x_{1t}$ at any $t$ induce changes in $x_{1,t+i}$ $i = 1, \ldots, t' - (t + 1)$, each of which contributes to an increase in $x_{1t'}$. Thus, the marginal revenue obtained from an increment of $x_{1t}$ early in the season is greater than that obtained from an increment later in the season. If $f_{x_1}^{\,1} = 0$, the marginal revenue is constant ($\lambda_1^{t'} = \lambda_1^t \;\forall\, t$) throughout the season.

In a similar manner, from (21), $\lambda_2^t$ is interpreted as the sum of marginal revenue lost in the current season plus the marginal discounted costs imposed on all future seasons when there is an incremental increase in the pest population ($x_{2t}$) at $t$. If $f_{x_{2t}}^{\,2} > 0$ and $f_{x_{2t}}^{\,1} < 0$, increases in $x_{2t}$ induce decreases in $x_{1,t+i}$ $i = 1, 2, \ldots, t' - (t + 1)$, each of which reduces $x_{1t'}$, in which case the shorter the period of time left for the compounding of an increase in $x_{2t}$, the less the marginal loss will be.

From (22), $\lambda_3^t$ is interpreted as the marginal benefit received from an incremental increase in the stock of pest susceptibility ($x_{3t}$) or as the sum of the marginal revenue from an increment of pest susceptibility in the current season plus the marginal discounted profits from this increment of pest susceptibility in all future seasons. Since $f_{x_3}^{\,3} \leqslant 0$, increases in $x_{3t}$ increase $x_{3,t+i}$, $i = 1, \ldots, t' - (t + 1)$, the marginal value of an increment of $x_{3t}$ decreases during the season.

Given the interpretations of the $\lambda_i^t$ as shadow prices of their corresponding $x_{it}$, the economic rationale for maximizing the Hamiltonian (8)

is as follows: The revenue obtained from increasing plant growth and decreasing pest growth from $t$ to $t+1$ is $\lambda_1^{t+1}(x_{1,t+1}-x_{1t})+\lambda_2^{t+1}(x_{2,t+1}-x_{2t})$, and the cost is $c(u_{1t},u_{2t})+\lambda_3^{t+1}(x_{3,t+1}-x_{3t})$. Thus, given the optimal $\lambda_i^t$, the Hamiltonian may be regarded as a static profit function at each $t$. Maximization of $H$ results in decision rules (9) and (10) regarding the use of $u_{1t}$ and $u_{2t}$, respectively. Since the interpretation of these rules is very similar, only (10) is discussed.

Using (18) to (22) and the fact $f_{u_{2t}}{}^{t}=\partial x_{i,t+1}/\partial u_{2t}$, (10) may be rewritten:

$$\begin{aligned}(24)\quad &\frac{\partial B_1}{\partial x_{1,t+1}}\frac{\partial x_{1,t+1}}{\partial u_{2t}}+\frac{\partial B_1}{\partial x_{2,t+1}}\frac{\partial x_{2,t+1}}{\partial u_{2t}}\\ &\quad+\frac{\partial B_2}{\partial x_{2,t+1}}\frac{\partial x_{2,t+1}}{\partial u_{2t}}\leqslant c_{u_{2t}}\\ &\quad+\frac{\partial B_1}{\partial x_{3,t+1}}\frac{\partial x_{3,t+1}}{\partial u_{2t}}+\frac{\partial B_2}{\partial x_{3,t+1}}\frac{\partial x_{3,t+1}}{\partial u_{2t}}.\end{aligned}$$

If less than holds in (24), $u_{2t}=0$; and if $u_{2t}>0$, equality holds. On the left-hand side of (24) are the marginal benefits resulting from insecticide use at $t$. The first term is the marginal value of $u_{2t}$ in increasing plant growth. The second and third terms are marginal values of insecticide use at $t$ in reducing pest growth. A reduction in pest growth at $t$ means less damage over the remainder of the season and an increase in current profits. In addition, reduced pest growth implies a lower terminal pest population and consequent increased profits in all future seasons.[6]

The three terms on the right-hand side of (24) comprise the marginal cost of insecticides. The first term is the marginal unit cost of materials. The last two terms are losses resulting from the depletion of the stock of susceptibility by an incremental increase in $u_{2t}$. The lower the stock of susceptibility at $t+1$, the higher the levels of $u_{2,t+i}$ $(i=1,\ldots,t'-t)$ required to maintain a given trajectory of the pest population for the remainder of the current season as well as for future seasons.

Interpretation of (24) is now straightforward. If the marginal value of insecticides in plant growth and pest growth is less than the marginal unit cost of insecticides plus the marginal cost of their use in reducing the stock of susceptibility, none will be used. If any insecticides are used, the level of use will be such that the marginal benefit equals the marginal cost.

It is instructive to relate this decision rule to that obtained in the "Economic Theory of Exhaustible Resources" (see, for example, R. G. Cummings [5]). If $c_{u_2}$ is taken to the left-hand side of (24), the only terms on the right-hand side are those involving $x_3$. Then the decision rule reads: Equate marginal profits at $t$ excluding resistance with marginal "user" costs. These user costs are increased future costs of controlling the pest as a result of a decision to apply chemicals today and are identical in nature to those which occur in production by extractive resource industries.[7]

It is generally agreed that growers attempt to drive the preceding marginal profits to zero at each time of application. Clearly, from (24), this is a nonoptimal behavior, given an appropriable pest population, and results in the present value of the stream of returns being less than that which would result if user costs were not ignored.

A generalization of the model to the case of $n$ decision-makers in the region, each of which regards the pest population in his field as nonappropriable, is straightforward and yields results similar to those found in other exhaustible resource industries, *viz.*, (1) competitive behavior on the part of the growers implies zero marginal profits for each and thus for the region; (2) centralized management implies marginal profits for each grower equal to a regionwide constant, the user costs associated with the common property stock of pest susceptibility; and (3) appropriate Pigouvian taxes and subsidies may be defined for the region to achieve the centralized solution with decentralized decision making and thus maximize regional profits.

It is also generally accepted that neglecting

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[6] The reader may obtain a better understanding of these marginal values by referring to the expanded versions of $\partial B_j/\partial x_{it+1}$ presented in equations (20), (21), and (22).

[7] The term "user cost" was coined by Keynes and has been widely employed in the field of natural resource economics. As defined by Scott [10, p. 34], user cost is "the present value of the future profit foregone by a decision to produce a unit of output today" and is thus an opportunity cost of current production. In natural resource industries, user costs resulting from current production may include (1) costs resulting from the deterioration and depletion of resource and (2) direct increases in future costs resulting from technical considerations (for example, increased future pumping costs from an acquifer as the water level declines).

It is recognized that the marginal profits excluding resistance also contain user cost items; but since this paper focuses on pest resistance, only user costs associated with this phenomenon are discussed.

the accumulation of resistance by growers leads to general overuse of chemicals. It is shown in the Appendix that this is not necessarily true. If "timing" counts in depletion of the stock of susceptibility, increases in the marginal value of the terminal stock will result in a larger terminal stock; but this may be accomplished by small reductions in chemical applications at times when the marginal effect is great and large increases when the marginal effect is small, the net result being an increase in chemical use over the season.

One further result is obtained in the case where insecticides are purchased competitively ($c_{u_{2t}}$ = a constant, $t = 1, \ldots, t' - 1$). The last two terms of (24) may be taken to the left-hand side; and for all $t$ such that $u_{2t} > 0$, optimal pesticide use implies that the net marginal benefits are equated.

## Implications of the Optimal Policy for the Economic Threshold

The concept of the threshold has attracted significant attention in literature. While some entomologists have referred to this concept as the critical level of pest population that causes damage [2], the economic literature on the subject has focused on the economic threshold defined as the level of pest population at which pest control is initiated [6, 7].

It has usually been assumed that the economic threshold is constant over the growing season, or it is implied by the analysis when only one application is allowed for the season [6, 7]. It is shown below that the economic threshold varies over time and under certain assumptions increases with time so that, the closer the harvest time, the higher is the level of pest population that will be tolerated before controls are applied.

Analysis proceeds under the simplifying assumptions that (1) the effectiveness of the pesticide during the current season depends only upon the stock of pest susceptibility at the beginning of the season [$h(x_{3t}, u_{2t}) = h(x_{3t_0}, u_{2t}) \; \forall \; t$], and (2) the rate of change in the stock of susceptibility is independent of its existing stock ($f_{x_{3t}}{}^3 = 0$). As a result of assumption (1), the stock of pest susceptibility is depleted with pesticide use during the current season, but only future seasons experience higher pest control costs to achieve a given level of control. This assumption is particularly appropriate for cases where the pest has one generation per season. Assumption (2) is made because it is felt that the effect of the changing stock of susceptibility on the rate of change in the stock is small *vis-à-vis* the effect of pesticide usage.

In the preceding section, the only necessary optimality condition that needs to be changed as a result of these assumptions is (13) which, since $f_{x_{3t}}{}^i = 0, i = 1, 2, 3$, becomes simply $\lambda_3{}^t - \lambda_3{}^{t+1} = 0$, implying that $\lambda_3{}^t = \partial B / \partial x_{3t'} \; \forall \; t$.

The decision rule (10) is rewritten

$$(25) \quad c_{u_2} \geqslant \lambda_1{}^{t+1} f_{u_2}{}^1 + \lambda_2{}^{t+1} f_{u_2}{}^2 - \lambda_3 f_{u_2}{}^3 = \phi(x_{2t}, u_{2t}, \lambda_1{}^{t+1} \lambda_2{}^{t+1}).$$

The plant size ($x_{1t}$) does not affect $\phi$ since $\partial\phi / \partial x_{1t} = 0$ [by taking the cross-derivatives of (1), (3), and (5)] and since $\lambda_3{}^t$ is time independent under the assumptions at this section. Thus, for constant $x_2$, $\phi(\cdot)$ decreases over time since $\lambda_1{}^t$ decreases with time and $\lambda_2{}^t$ (which is negative) increases with time. By taking the cross-derivatives of (1), (3), and (5), one obtains $f_{u_2x_2}{}^1 \geqslant 0$ (if $m_{zz} \geqslant 0$), $f_{u_2x_2}{}^2 \leqslant f_{u_2x_2}{}^3 = 0$ which result in $\phi_{x_2} \geqslant 0$. It is therefore concluded that, if $\hat{x}_{2t}$ is the economic threshold at time period $t$—i.e., $\phi(\hat{x}_{2t}, u_{2t}, \lambda_1{}^{t+1}, \lambda_2{}^{t+1}) = c_{u_2}$ for some $u_2$ with strict inequality holding $\forall \; x_2 < \hat{x}_{2t}$ and $\forall \; u_2$—then at $t+1$ $\phi(x_{2,t+1} = \hat{x}_{2t}, \ldots) < c_{u_2} \; \forall u_2$ and a higher $x_{2,t+1}$ would be required to bring (25) to equality and positive pesticide application. This proves that the economic threshold increases over time.[8] It is further noted that the same result holds if pest susceptibility is either nonexistent or excluded from the decision-makers' consideration. If the assumptions of this section do not hold, changes in $x_{3t}$ affect $\phi(\cdot)$ in different directions; and it is impossible to know the direction of the change in the economic threshold. It is, however, inconceivable that there are reasonable conditions that would keep it constant throughout the season.

## Concluding Remarks

A pest management model has been presented which, when specialized and applied to a

[8] In equation (25) it was tacitly assumed that the marginal effects of pest control ($u_2$) on both the plant and pest growth ($f_{u_2}{}^1$ and $f_{u_2}{}^2$) are time independent. This may not be the case if, for example, there are some critical stages in the life of the plant where it would be more vulnerable to pest attacks so that the marginal damage during fruiting or seedling stages would be more detrimental to crop size than at other stages. In such cases, for any fixed $x_2$, $\phi$ may rise over time rather than drop, and our result would not hold.

particular crop, results in optimal timing of optimal amounts of pesticides when pest resistance is increasing. An economic interpretation has been provided, and decision rules have been developed for optimal pesticide use at any time during the season. It was found that optimal use at any time implies that the marginal profits, excluding susceptibility, are equated to a user cost resulting from depletion of the stock of susceptibility.

A result of the analysis of the optimal time path of pesticide use is that the economic threshold varies during the course of the season rather than remaining fixed at a particular level as usually presented in the entomological literature. Also, a comparative dynamic analysis yielded the interesting conclusion that only under very restrictive assumptions does the neglect of resistance result in overuse of chemicals.

A few caveats are in order, however. First, throughout this paper it was assumed that there are no externalities associated with pesticide use and, thus, the resulting policy may not be socially optimal. Secondly, it was assumed that nonmaterial pest control costs such as application costs are negligible. Third, the uncertainty which arises in many pest control situations was ignored.[9] Fourth, the effect of alternative pest control techniques, including natural controls such as parasites and predators, was not considered.[10] Each of these areas deserves investigation.

Some entomologists and systems scientists have argued that, because of the externalities associated with pesticide use and the inevitability of resistance, pesticides should be discarded as a control measure in favor of biological, cultural, and other nonchemical controls. The models developed by those who hold this view are generally simulation rather than optimization models which investigate the "natural" biological dynamics. Hopefully, this model illustrates the fact that, even where it is possible to "fully extract" pest susceptibility, it may be optimal to use pesticides. Not to allow this possibility would be analogous to not allowing a petroleum producer to pump from a reservoir under any conditions.

Following the analogy with extractive resource industries somewhat further, this paper concludes by suggesting that a possible productive line of future research would be to view research and development expenditures by agrochemical firms as similar to exploration costs in extractive industries. An operational two-sector model could then be developed which would simultaneously determine the optimal discovery and extraction of pest susceptibility by the agrochemical sector and the agricultural sector, respectively.

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[9] For an analysis of pest management decision making under uncertainty, the reader is referred to Carlson [3].

[10] Natural density-dependent factors are indirectly taken into account by allowing the natural growth function $[g(z_t, t)]$ be a function of time. It is possible for $g$ to have an upper bound which would imply a zero level of application for all time.

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## APPENDIX A

This appendix investigates one effect of bringing pest susceptibility into consideration. By casting the problem in a static optimization framework, it is shown that increasing the terminal benefits of pest susceptibility will have the effect of increasing the optimal terminal stock of susceptibility at the end of the season; however, it is not clear whether the total amount of pesticides applied throughout the season will increase or decrease.

Define: $u_i = (u_{i1} \ldots u_{it} \ldots u_{it'})$ $i = 1, 2$; then the terminal states can be written in a static framework.

$$x_{1t'} = g^1(u_1, u_2) \tag{A.1}$$

$$x_{2t'} = g^2(u_2) \tag{A.2}$$

$$x_{3t'} = g^3(u_2). \tag{A.3}$$

Assume that the terminal benefits function is separable;

$$B_1(x_{1t'}) + B_2(x_{2t'}; x_{3t'}) = \epsilon_1\,\psi_1(x_{1t'}) + \epsilon_2\,\psi_2(x_{2t'}) + \epsilon_3\,\psi_3(x_{3t'})$$

with $\epsilon_i \geqslant 0$ and $\psi'_1 \geqslant 0$, $\psi'_2 \leqslant 0$, $\psi'_3 \geqslant 0$. Then the problem is

$$\max J = \sum_{i=1}^{3} \epsilon_i\,\psi_i(x_{it'}) - \sum_{t=1}^{t'} c(u_{1t}, u_{2t}) \tag{A.4}$$

subject to (A.1), (A.2), and (A.3).

Necessary and sufficient conditions for an interior solution $u^*_i$ $(i = 1, 2)$ are

$$\frac{\partial J}{\partial u_i} = 0 \qquad i = 1, 2 \tag{A.5}$$

$$\frac{\partial^2 J}{\partial u_1\,\partial u_2} = \begin{bmatrix} \epsilon_1\,\psi'_1\,g^1_{u_1u_1} & 0 \\ 0 & \sum_{i=1}^{3} \epsilon_i\,\psi'_i\,g^i_{u_2u_2} \end{bmatrix} \tag{A.6}$$

is negative definite where $\psi'_i = \phi\partial\psi_i/\partial g^i$ and $g_{u_1u_2}{}^1 = 0$ can be obtained from equation (3).

Using (A.1) to (A.3) and (A.5), the effect of increasing the benefits of pest susceptibility is derived at the terminal time period by comparative static analysis (e.g., see Intriligator [8, pp. 196–200]). From the fundamental matrix equation of the system

$$\begin{bmatrix} -1 & 0 & 0 & g^1_{u^*_1}{}^{\mathrm{Tr}} \;\ldots & g^1_{u^*_2}{}^{\mathrm{Tr}} & \ldots \\ 0 & -1 & 0 & 0 & g^2_{u^*_2}{}^{\mathrm{Tr}} & \ldots \\ 0 & 0 & -1 & 0 & g^3_{u^*_2}{}^{\mathrm{Tr}} & \ldots \\ 0 & 0 & 0 & \epsilon_1\,\psi'_1\,g^1_{u^*_1u^*_1} & 0 & \\ \vdots & \vdots & \vdots & 0 & \sum_{i=1}^{3} \epsilon_i\,\psi'_i\,g^i_{u^*_2u^*_2} & \\ \vdots & \vdots & \vdots & & & \end{bmatrix} \begin{bmatrix} \frac{\partial x_1}{\partial \epsilon_3} \\ \vdots \\ \frac{\partial u_1}{\partial \epsilon_3} \\ \vdots \\ \frac{\partial u_2}{\partial \epsilon_3} \\ \vdots \end{bmatrix} = \begin{bmatrix} 0 \\ \vdots \\ \\ \\ -\psi'_3\,g^3_{u_2} \\ \vdots \end{bmatrix}$$

where $g^i_{u_j}$, $\partial x_1/\partial \epsilon_3$, $\partial u_j/\partial \epsilon_3$ are $t' \times 1$ vectors; $g^i_{u_j u_j}$ is a $t' \times t'$ matrix; and Tr indicates transpose. Then,

(A.7)

$$\frac{\partial x_{3t'}}{\partial \epsilon_3} = -g^3 u_2 \left[ \sum_{i=1}^{3} \epsilon_i \, \psi'_i \, g^i_{u^*_2 u^*_2} \right]^{-1} g^3_{u_2} \, \psi'_3 \geqslant 0$$

(A.8)

$$\frac{\partial u_{2t}}{\partial \epsilon_3} = \left[ \sum_{i=1}^{3} \epsilon_i \, \psi'_i \, g^i_{u^*_2 u^*_2} \right]^{-1} g^3_{u_2} \, \psi'_3 \lesseqgtr 0.$$

The inequality in (A.7) is obtained by the assumptions of negative definite $\partial^2 J/\partial u_i \partial u_j$ and $\Psi'_3 \geqslant 0$. This result shows that the level of optimal susceptibility at the terminal period is a monotone nondecreasing function of its contribution to future profits. However, the undetermined sign of (A.8) shows that one cannot tell the changes in the levels of pesticide application ($u_{2t}$) as a result of bringing susceptibility into the consideration of the decision makers. One can be certain that an increase in $\epsilon_3$ will decrease pesticide application ($u_{2t}$) *only* if it is optimal to apply once during the season.

# *Short Articles and Notes*

## Short and Long Run Elasticities in Consumer Demand Theory*

ABRAHAM SUBOTNIK

**Contrary to statements frequently made in the literature, the own elasticity of demand is not necessarily smaller in the short run than in the long run. It is also shown that the availability of new commodities will not necessarily increase the own elasticity of demand for the existing commodities.**

*Key words:* **demand elasticities; length of run; new commodities.**

IT IS USUALLY thought that the own elasticity of demand for any commodity is smaller in the short run than in the long run. Evidence of this line of thought is not difficult to find. Friedman [1] states that "in the shortest of all runs, where conditions are allowed to vary very little, one would expect the demand curve to have the least elasticity. As the range of conditions which are allowed to vary is widened, one would expect the elasticity of the demand curve to increase." Similarly, Nerlove [4] concludes that the long run elasticity of demand is larger because as prices fall, consumers would demand more of the product provided they have time to adjust, the reason being that "they always have the alternative of consuming less than that amount." Analyzing the factors affecting the changes in demand elasticity through time, Stigler [7] comes to the same conclusion, namely, that long run own elasticity of demand increases with the length of time in which a price change persists.[1]

While such statements are common place, there does not seem to exist in the literature any formal proof regarding their validity.[2] The purpose of this note is to show that, contrary to prevailing thinking, own elasticities of consumer demand are not necessarily larger in the long run. Actually, it seems that the reason for the heuristic feeling that own elasticity of demand is larger in the long run is based on arguments related to the effect of the run on elasticity of the own-substitution term. As will be shown, this elasticity is the one which increases with the run.

It will also be shown that the methodology for comparing long run and short run elasticities of demand may also be useful in analyzing the effects of the appearance of new consumer goods in the market. As will be shown, the availability of new consumer goods will not necessarily increase the own elasticity of demand for the old products.

The procedure for comparing long run to short run elasticities, as applied to the theory of the firm, has been presented by Mundlak [2, 3]. As a result of the Le-Chatelier principle (see also Samuelson [6]), these long run own elasticities are always larger than the short run elasticities. Since in consumer demand theory, the total effect of a price change on the quantity demanded depends not only on a substitution effect but also on an income effect, one cannot rely on the Le-Chatelier principle when comparing long run to short run own elasticities of demand.

The analysis is carried out as follows: assuming one begins at an initial long run position, one proceeds by restricting the possibilities of

* I am grateful to Dr. J. Paroush for his helpful comments.

[1] It may be argued that the above quotations relate to the compensated demand function. If so, these statements are correct. But from the context in which these quotations appear, it does not seem that they relate to the compensated demand function.

[2] While this note is concerned with the effect of length of run on the "pure" elasticity of consumer demand theory, others have analyzed that problem on measured demand elasticities. Unlike the "pure" elasticities, measured elasticities reflect also the effects on demand of interacting change of prices in the market. See [5]. They also claim that for commodities demanded for consumption (unlike demand for changes in storage), demand in the long run is more elastic.

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adjusting the levels of consumption of some products when prices change. Resulting changes in consumption of the remaining products are regarded as short run changes. These short run changes are then compared with the corresponding long run changes obtained when the consumer is free to adjust optimally the level of consumption of all commodities as prices change.

The analysis begins with the long run equilibrium position of the consumer who maximizes his utility function under a budget constraint and assumes that all necessary and sufficient conditions hold. Then the changes in the quantities demanded, resulting from autonomous changes in prices and income, are derived from the following system:

(1)

$$\begin{bmatrix} 0 & u_1 & \cdots & u_n \\ u_1 & u_{11} & \cdots & u_{1n} \\ \vdots & & & \\ u_n & u_{n1} & \cdots & u_{nn} \end{bmatrix} \begin{bmatrix} d\hat{\lambda} \\ dx_1 \\ \vdots \\ dx_n \end{bmatrix} = \lambda \begin{bmatrix} dI - \Sigma x_i dp_i \\ dp_1 \\ \vdots \\ dp_n \end{bmatrix}$$

where

$$d\hat{\lambda} = -\frac{d\lambda}{\lambda}.$$

Let

$y_1$ represent the vector of $x_1, \ldots, x_m$,

$y_2$ represent the vector of $x_{m+1}, \ldots, x_n$

$z_1$ represent the vector of the prices of $x_1, \ldots, x_m$,

and

$z_2$ represent the vector of the prices of $x_{m+1}, \ldots, x_n$.

The long run equilibrium system may then be written as:

(2)

$$\begin{bmatrix} 0 & v'_1 & v'_2 \\ v_1 & v_{11} & v_{12} \\ v_2 & v_{21} & v_{22} \end{bmatrix} \begin{bmatrix} d\hat{\lambda} \\ dy_1 \\ dy_2 \end{bmatrix} = \lambda \begin{bmatrix} dI - \Sigma y_i dz_i \\ dz_1 \\ dz_2 \end{bmatrix}$$

where the elements of the matrix in (2) are the corresponding subpartitions of the matrix in (1).

It is assumed now that once the long run equilibrium is reached, the consumer is not allowed to adjust his consumption of commodities $x_{m+1}, \ldots, x_n$ as prices change. Therefore, the definition of the short run implies $dy_2 = 0$. The short run response to changes in prices and in income will now be obtained from the solution to the following system:

$$(3) \quad \begin{bmatrix} 0 & v'_1 \\ v_1 & v_{11} \end{bmatrix} \begin{bmatrix} d\hat{\lambda} \\ dy_1 \end{bmatrix} = \lambda \begin{bmatrix} dI - y_1 dz_1 \\ dz_1 \end{bmatrix}.$$

But from the inverse[3] of the augmented matrix in (2), it follows that

$$(4) \quad \begin{bmatrix} 0 & v'_1 \\ v_1 & v_{11} \end{bmatrix}^{-1} = \begin{bmatrix} 0_{-1} & v'_{-1} \\ v_{-1} & v_{-11} \end{bmatrix} - \begin{bmatrix} v'_2 \\ v_{12} \end{bmatrix} (v_{-22})^{-1} [v_{-2} \; v_{-21}].$$

The minuses preceding the subscripts mean that the respective sub-matrices correspond to the sub-matrices appearing in the inverse of the augmented matrix in (2).

It follows that the short run response to a change in price is

$$(5) \quad \frac{\partial \bar{y}_1}{\partial z_1} = \lambda\{(v_{11}^{-1}) - y_1(v_1^{-1})\},$$

and the long run response is

$$(6) \quad \frac{\partial y_1}{\partial z_1} = \lambda\{v_{-11} - y_1 \, v_{-1}\}.$$

Substituting (4) in (5), the difference between short and long run response is given as follows:

$$(7) \quad \frac{\partial \bar{y}_1}{\partial z_1} - \frac{\partial y_1}{\partial z_1} = -\lambda\{v_{-12}(v_{-22})^{-1}v_{-21} - y_1 v_{-12}(v_{-22})^{-1}v_{-2}\}.$$

Assume that, as a result of a price change, the consumer is allowed to adjust the quantities demanded of all commodities but the last one—the $n$th. Then,

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[3] Let the matrix in (2) be

$$\begin{bmatrix} 0 & v'_1 & v'_2 \\ v_1 & v_{11} & v_{12} \\ v_2 & v_{21} & v_{22} \end{bmatrix} \qquad \begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix} = N;$$

namely, the matrix $N_{11}$ is the same matrix as in (3). By an obvious notation, the following has to hold:

$$\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix} \begin{bmatrix} N^{11} & N^{12} \\ N^{21} & N^{22} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}.$$

The pertinent relations for obtaining (4) are:

$$(4.1) \quad N_{11}N^{11} + N_{12}N^{21} = 1$$

$$(4.2) \quad N_{11}N^{12} + N_{12}N^{22} = 0.$$

From (4.1) and (4.2) we solve for $N_{11}^{-1}$ in terms of the elements of the inverse of $N$. The result is (4.3) $N_{11} = N^{11} - N^{12}(N^{22})^{-1}N^{21}$. The relation between (4.3) and (4) is straightforward.

$$(8)\quad \frac{\partial \bar{x}_k}{\partial p_k} - \frac{\partial x_k}{\partial p_k} = -\frac{v_{-kn}}{v_{-nn}} \lambda\{v_{-nk} - x_k v_{-n}\},$$

but

$$\frac{\partial x_n}{\partial p_k} = \lambda\{v_{-nk} - x_k v_{-n}\}$$

is the long run change in the quantity demanded of commodity $n$ when the price of commodity $k$ was changed. Therefore,

$$(9)\quad \frac{\partial \bar{x}_k}{\partial p_k} - \frac{\partial x_k}{\partial p_k} = -\frac{v_{-kn}}{v_{-nn}} \frac{\partial x_n}{\partial p_k}.$$

There is no reason to believe that, in general, the short run own elasticity of demand will be smaller than the long run elasticity of demand. For this to happen the sign of $\partial x_n / \partial p_k$ has to be equal to the sign of $v_{-kn}$ since $v_{-nn}$, being the own substitution effect of the $n$th commodity, has to be negative. This may happen when the real income effect for $x_n$ is small.[4]

It is easy to show that the own substitution term has to be smaller in the short run than in the long run. From (8) is obtained

$$(10)\quad \frac{\partial \bar{x}_k}{\partial p_k}\bigg|_{u^o} - \frac{\partial x_k}{\partial p_k}\bigg|_{u^o} = -\lambda \frac{v_{-kn}{}^2}{v_{-nn}} > 0.$$

This is the Le-Chatelier principle when applied to consumer demand theory.

The application of the above framework for analyzing the effects of the availability of new consumer goods on the own elasticities of demand for the existing goods is straightforward.[5] Initially, before the appearance of the new consumer goods in the market, the slopes of the demand functions at equilibrium are given by the solution of the system represented at (3). When, at this equilibrium, new products appear in the market, the slopes of the demand functions will be given by the solution to the system represented by (2). The vectors $y_2$ and $z_2$ now represent the quantities and the prices, respectively, of the new products.

Following the above procedure, relation (9) is derived; it now represents the difference between the slopes of the demand function for commodity $k$ when commodity $n$ is not available in the market, and the corresponding slope when commodity $n$ is available in the market.

Again, only if the real income effect for the new commodity is small will there be an increase in the own elasticity of demand for commodity $k$ when the new commodity becomes available in the market.

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[4] In the case of only two commodities, $x_1$ and $x_2$, where in the short run the consumer is restricted to adjusting his consumption of $x_1$ only, relation (9) becomes

$$p_1 \frac{\partial \bar{x}_1}{\partial p_1} - p_1 \frac{\partial x_1}{\partial p_1} = p_2 \frac{\partial x_2}{\partial p_1}.$$

Clearly, the long run own elasticity of demand for $x_1$ will be larger than its short run elasticity only if the long run quantity demanded of $x_2$ will increase as the price of $x_1$ increases. For this to happen it is sufficient that at the neighborhood of equilibrium the utility function is homogeneous and that the elasticity of substitution between $x_1$ and $x_2$ is larger than 1.

[5] It is assumed that the availability of new commodities does not effect the utility function.

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# On Exact Multicollinearity and the Estimation of the Cobb-Douglas Production Function*

JOHN P. DOLL

**The assumptions of the economic model underlying the traditional Cobb-Douglas production function analysis imply that exact multicollinearity should exist among the inputs. Restricted estimation procedures may lead to parameter estimates with additional economic content. Conventional methods of input aggregation and model specification may result in biased or misinterpreted estimates.**

*Key words:* **Cobb-Douglas; multicollinearity.**

THIS PAPER explores some of the implications of exact multicollinearity upon the empirical estimation of the Cobb-Douglas production function and makes some references to problems caused by "nearly exact" multicollinearity. Although its popularity has waxed and waned depending upon current trends within the profession, the Cobb-Douglas model has been widely used in agricultural economics. In view of the voluminous literature, it is perhaps presumptuous to suppose that anything new can be said. In fact, because of this vested interest, every possible avenue should be explored. Hopefully, this paper will provide some insights for interpreting works already published and will be useful for formulating and interpreting future studies. The implications may also carry over to other algebraic forms of production functions.[1]

The paper is divided into two sections. First, implications of the assumptions of the economic analysis upon the presence of multicollinearity are discussed. Then the impact of multicollinearity upon the applied problems of input aggregation, specification error, and the inclusion of "management" in the production function are analyzed.

## Multicollinearity and the Assumptions of the Economist

Multicollinearity arising in least squares estimation of the Cobb-Douglas model is not new—it is a problem that emerged with the model itself. When evaluating the 1928 work of Cobb and Douglas [6], Mendershausen [19] noted in 1938 the high correlations among the "independent" variables used by Cobb and Douglas. He suggested that the estimates obtained by Cobb and Douglas were not trustworthy and simply reflected a time trend among the variables.

Modern econometric theory suggests that multicollinearity may lead to problems of structural estimation and specification error. The rationale underlying this statement is readily available in recent literature and will not be repeated here.[2] Interestingly enough, very little attention has been directed towards analyzing the impact of the assumptions of the economic analysis upon multicollinearity. This section is directed to that end.

It is not an easy task to determine the assumptions made by economists applying the Cobb-Douglas function. In part this is due to the fact that the model has been applied to many types of situations. Douglas and his co-workers applied it to a time series analysis of all manufacturing [6] and to cross-section data including all types of industry groups [3]. In agriculture the model has been applied to single enterprise

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[1] The model to be discussed here is the traditional single equation model used in agricultural economics in which the inputs are assumed exogenous and output endogenous. A discussion of simultaneous equation models is presented by Malinvaud [17, p. 517], Zellner, Kmenta, and Dreze [26], Mundlak and Hoch [21], and Nerlove [22]. Their interpretations stem from the early work of Marshak and Andrews [18].

It seems safe to assume that simultaneous equation models will also have multicollinearity problems, and, if so, the present discussion might also have value for users of such models. Because of the volume of published work on the Cobb-Douglas function, I cannot begin to cite all relevant literature on each topic discussed; therefore this article should not be regarded as a review article on Cobb-Douglas production functions.

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[2] A development of the concepts of estimable functions and multicollinearity as used in this section may be found in Theil [24, pp. 147–152], Chipman [4] and [5], Malinvaud [17, pp. 187–197], and Walters [25, pp. 288–293]. A working paper is also available from the author upon request.

farms, multiple-enterprise farms and to single enterprises found existing on multiple-enterprise farms [11, p. 220]. This diversity suggests that the underlying assumptions might be quite different. But it has also been true that users of the function have not always stated the assumptions needed to justify their economic analysis, leaving the reader to reason backwards towards the underlying economic models.

Although types of assumptions needed for the different models should be examined with considerable care, the purpose of this paper can be adequately served by considering the most elementary case. Suppose that the Cobb-Douglas production function is to be estimated from a cross-section sample of single enterprise farms. Then, the usual assumptions of the economist are (1) a given percentage increase in input results in the same percentage increase in output for all firms, that is, the production coefficients are identical for all firms, (2) each individual firm maximizes profit, and (3) all firms face the same input and output prices.[3] The mathematical model is

$$(1) \qquad Y_i = \beta_0 X_{i1}{}^{\beta_1} X_{i2}{}^{\beta_2} \exp(\epsilon_i)$$

where the dependent variable $Y_i$ is some measure of output, $X_{i1}$ and $X_{i2}$ are "independent" variables representing some measure of the inputs, and the $\beta_j (j = 0, 1, 2)$ are unobserved population parameters that are assumed to be positive. $\epsilon_i$ is the unobserved random error.

When estimated from cross-section data, this function is often interpreted as the long-run production function for farms in the sample, on grounds that inputs fixed on individual farms will vary among farms.[4] Ideally, inputs and outputs are measured as service flows provided or produced over the appropriate time period.

The assumption of cost minimization implies that for any farm

$$\frac{MPP_1}{P_1} = \frac{MPP_2}{P_2}$$

where the $MPP_j$ are the marginal physical products and the $P_j$ are unit prices. For the Cobb-Douglas model, this implies

$$(2) \qquad X_{i1} = \frac{\beta_1 P_2}{\beta_2 P_1} X_{i2} = dX_{i2},\ d = \frac{\beta_1 P_2}{\beta_2 P_1},$$

and the inputs are used in proportional amounts. But assumptions one and three insure that the $\beta_j$ and prices are identical for all farms. All farms are on the long-run expansion path, and input use must be proportionate on each farm in the sample. Farmers do not have to be profit maximizers to insure this—cost minimization is sufficient. If returns to scale are less than unity and all farms were in long-run equilibrium, all would use exactly the same quantities of inputs, as well as proportions. If returns to scale were unity or increasing, the farms might be at any point on the expansion path—the particular point determined in each case by exogenous factors.[5]

When input use is proportional but not equal on all farms and the Cobb-Douglas model is valid, then exact multicollinearity results. If $X_{i1} = dX_{i2}$, then $\log X_{i1} = \log d + \log X_{i2}$. This holds exactly for all $n$ observations in the sample so that

$$\begin{bmatrix} 1 \ \log X_{11} \ \log X_{12} \\ \cdots\cdots\cdots \\ 1 \ \log X_{n1} \ \log X_{n2} \end{bmatrix} \begin{bmatrix} -\bar{d} \\ 1 \\ -1 \end{bmatrix} = \begin{bmatrix} 0 \\ \vdots \\ 0 \end{bmatrix}$$

where $\bar{d} = \log d$. By defining $Q' = [-\bar{d}, 1, 1]$ and $w = [w_1, w_2, w_3]$, then it follows from the theory of estimable functions that any value of $w$ such that $wQ = -dw_1 + w_2 - w_3 = 0$ determines an estimable function of $\beta$.

Many of the estimable functions will have no economic meaning. One of considerable importance for the Cobb-Douglas function is $w_r = [0, 1, 1]$, which sums the input coefficients and thus measures returns to scale. Fortunately, for the example here, $w_r Q = 0$ so that $(\beta_1 + \beta_2)$ may be estimated from the sample data; the estimate can be obtained by dropping $X_{i1}$ (or $X_{i2}$) from the statistical model. Thus, it is possible to measure returns to scale even when inputs are perfectly correlated. In a similar manner, it may be possible to estimate returns from other combinations of perfectly correlated inputs.

This demonstrates that if the economic assumptions hold, then all parameters in the

[3] These are as presented by Nerlove [22] in Chapters 1 and 2. For discussions and useful bibliographies, see the references in Walters [25, pp. 289–290, footnote 1] and Kehrberg [15].

[4] Problems of units of measure are discussed by Nerlove [22, pp. 11–14] and Heady and Dillon [11, Ch. 7]. Interpretation of cross-section versus time-series data is discussed by Klein [16, Chs. 2 annd 3].

[5] When the $\beta_j$ and $P_j$ vary slightly among farms, then nearly-exact multicollinearity may occur. For a discussion of the long-run equilibrium, see Walters [25, p. 290], Heady and Dillon [11, p. 217], and the references they cite.

model cannot be estimated by ordinary least squares. In fact, if the economic assumptions do hold, the rank of the matrix of observed "independent" variables, usually denoted $X$, would be two (when input use is proportionate but not equal). Thus, users of the Cobb-Douglas model who are dismayed to find multicollinearity among the "independent" variables should be pleased because the presence of multicollinearity serves as a verification of their economic model.

Equation (2) is the expansion path of the firm, and $d$ can therefore be computed from the sample data. Using the input prices, the estimate of $d$, and the least squares estimates of $(\beta_1 + \beta_2)$, estimates of $\beta_1$ and $\beta_2$ can be obtained from[6]

$$\beta_1 = d \frac{P_1}{P_2} \beta_2 \tag{3}$$

and

$$\beta_2 = \frac{P_2(\beta_1 + \beta_2)}{P_2 + P_1 d}. \tag{4}$$

The above analysis assumes all farms will use input proportions that fall on the long-run expansion path. This could arise because all inputs are variable or because some inputs are fixed but the farmer is a cost-minimizer. This second condition might not be unreasonable, given the uncertainty farmers face, but the analysis can be extended to the case of fixed inputs.

Suppose that $X_{i1}$ is fixed and $X_{i2}$ is variable. Then, in the short run, the farmer will maximize profits by equating the value of the marginal product of $X_{i2}$ to $P_2$. But the expression

$$Py\, MPP_2 = P_2$$

can be solved to express the variable input as a function of the amount of fixed input present on the farm as follows:

(5)

$$X_{i2} = (Py\, \beta_0\, \beta_2\, P_2{}^{-1})^{\frac{1}{1-\beta_2}}\, X_{i1}{}^{\frac{\beta_1}{1-\beta_2}} = gX_{i1}{}^{h}$$

where $Py$ is the unit price of output and all other variables are as defined previously.

Expression (5) cannot be expected to coincide with the long-run expansion path. $X_{i2}$ will be a monotone increasing function of $X_{i1}$ that will increase at an increasing, constant, or decreasing rate depending upon the returns to scale. For increasing or decreasing returns to scale, (5) will cross the long-run expansion path (2) at some point. For constant returns to scale, the two will diverge unless $d = g$.

Because the variable input is an exponential function of the fixed input, the two will not be perfectly correlated using the linear (product-moment) correlation coefficient. The actual correlation in the sample will depend on the degree of curvature in (5) and the spread of observed values of the fixed input in the sample. If the sum of $\beta_1$ and $\beta_2$ is close to one, as is likely in many agricultural applications, then (5) will approach linearity and nearly-exact multicollinearity may exist. In this case, $X'X$ may be inverted and least squares estimates of $\beta_1$ and $\beta_2$ obtained. These estimates will have the usual unfortunate properties associated with high multicollinearity.

Equation (5) is linear in logarithms. Thus, $g$ and $h$ may be readily estimated from the sample data. A least squares estimate of $(\beta_1 + \beta_2)$ could be obtained by dropping either $X_{i1}$ or $X_{i2}$ from the statistical model. Call this estimate $l$. Then estimates of $\beta_1$ and $\beta_2$ could be obtained by solving simultaneously

$$\beta_1 + \beta_2 = l$$
$$\beta_1 + h\beta_2 = h,$$

provided $h \neq 1$. Depending upon the degree of multicollinearity, estimates obtained in this manner may have more economic content than conventional estimates.

The estimation procedures of this section have been derived to clarify the economic logic involved. However, the problem can be formulated using restricted least squares regression. For exact multicollinearity, the problem is to estimate (1) subject to the restriction $(P_2\beta_1 - dP_1\,\beta_2 = 0)$, and the estimates of $\beta$ are conditionally unbiased given this restriction. For nearly exact multicollinearity, the restriction would be $(h - h\,\beta_2 - \beta_1 = 0)$. When the prior

[6] The reader will note we are regarding the statistical model obtained by omitting $X_{i1}$ or $X_{i2}$ from (1) along with the identity (2) as a two equation model, the coefficients of which are solved for estimates of the $\beta_j$. Thus, (2) can be regarded as an "identifying" restriction. For $k$ inputs, there would be ($k$-1) identities in (2). When nearly exact multicollinearity exists, the equations in (2) could be estimated by least squares. A common practice when the two input variables are found to be perfectly correlated involves dividing the dependent variable and the remaining independent variable by one of the two perfectly correlated inputs and estimating an equation based on the averages. Factor shares can also be used under the assumption of constant returns to scale [25, p. 290].

restrictions are correct, the restricted estimates will be more efficient than the unrestricted estimates. However, even when the prior restrictions are incorrect, they can lead to an increase in efficiency if they are only "slightly" incorrect. Theil discusses this point [24, p. 546].

## Some Applications to Empirical Research Problems

### Inputs

It is common in empirical studies using the Cobb-Douglas function to aggregate many of the input categories found on farms. The two general rules for input aggregation are:[7]

1. The inputs within an individual category should be as nearly perfect substitutes or perfect complements as possible.
2. Relative to each other, the categories of inputs should be neither perfect substitutes nor perfect complements.

On the aggregation of perfect complements, Heady and Dillon [11, p. 217] say, "First, perfect complements, i.e., resource categories that have to be used in fixed proportions, should be treated as a single input. The use of one input implies the use of its complements. To include each of the complementary categories would lead to multicollinearity because of perfect correlation between levels of the complementary inputs." Two methods have been used to aggregate inputs: additive and multiplicative aggregation. Heady and Dillon [11, p. 229] prefer multiplicative aggregation.

Although quite different from the standpoint of economic logic, in the observed sample data perfect complements would appear similar to substitutes combined in cost-minimizing proportions. That is, complements, such as tractors and tractor drivers, would be perfectly correlated but so would substitutes, say land and capital, combined along expansion path (2). Therefore, *all* input categories observed should be perfectly correlated—given the assumptions of the previous section when all inputs are variable. Even when perfect correlation is not found, aggregating inputs into categories with the statistical objective of minimizing correlation among categories seems to have little to defend it from either the theory of the firm or the logic of the Cobb-Douglas model. In fact, the Cobb-Douglas model imposes the property that all input categories must be substitutes with an elasticity of substitution of one. Perhaps this consideration, if indeed it is operational, should be used to guide aggregation. Finally, the application of the marginal productivity theorem, which the Cobb-Douglas model is often used to test, requires that all inputs categories be substitutes [7]. In general the use of the two aggregation rules stated above should receive further critical examination. However, they have been widely utilized in agricultural economics research, and an examination of their implications is therefore in order.

The discussion of exact multicollinearity presented above leads to the conclusion that when inputs are perfectly correlated, no aggregation is needed. In the two input case, one input can be omitted and the regression including the other will yield an estimate of $(\beta_1 + \beta_2)$. But what happens when they are aggregated?

Supposing $X_{i1}$ and $X_{i2}$ are related by (2) and linear unweighted aggregation is used, then $X_{i1} + X_{i2} = dX_{i2} + X_{i2}$. The correct economic model is (1) and the correct statistical model is (1) with one variable omitted. But when linear unweighted regression is used, the estimate of $\alpha_1$ in the following expression

$$Y_i = \alpha_0(X_{i2} + dX_{i2})^{\alpha_1} \exp(\epsilon_i)$$

is used to estimate $(\beta_1 + \beta_2)$. Changing this expression to logarithmic form gives

$$\log Y_i = [\log \alpha_0 + \alpha_1 \log (1 + d)] + \alpha_1 \log X_{i2} + \epsilon_i,$$

and the constant term is biased, but the slope is not. That is, $\alpha_1 = (\beta_1 + \beta_2)$ where $(\beta_1 + \beta_2)$ could also be estimated by dropping $X_{i1}$. Next, when multiplicative aggregation is used, then $X_{i1}X_{i2} = dX_{i2}X_{i2}$. Again, (1) with a variable omitted would give unbiased estimates of $\beta_0$ and $(\beta_1 + \beta_2)$, but

$$Y_i = \delta_0(dX_{i2}X_{i2})^{\delta_1} \exp(\epsilon_i)$$

or

$$\log Y_i = [\log \delta_0 + \delta_1 \log d] + \delta_1 2 \log X_{i2} + \epsilon_i.$$

Thus, the independent variable is doubled in magnitude, and the constant term is again biased. In fact, $\delta_1 = \frac{1}{2}(\beta_1 + \beta_2)$ and the true effects are underestimated. The bias in $\delta_1$ (as an estimator of $\beta_1 + \beta_2$) can be removed by using the geometric mean of the independent variables as

[7] These are as presented by Heady and Dillon [11, p. 220]. They do not cite a source. The rules have appeared various places in the literature; the earliest rule I have found is in Bradford and Johnson [1, p. 133].

the aggregated variable. As a reminder, notice again that $\alpha_1$ and $\delta_1$ measure the summed effects of all perfectly correlated inputs—not the individual effect of any one input.

## Specification errors

The two types of specification errors are omitting variables from the regression model that are in fact included in the true production model or including variables in the regression model that are not contained in the true model. Much has been said about specification errors for production models, and all facets of the problem cannot be considered here.[8] Again, only the implications of exact multicollinearity will be explored.

Considering specification errors of the first type, it is important to note that the model specified can never be estimated because of the presence of exact multicollinearity. Some variables included in the theoretical specification will always have to be omitted from the actual regression to be estimated (or alternatively, restricted regression will have to be used). The point is that the correct model should always be specified even though it cannot be estimated. To do otherwise will lead to misinterpretation of meaning of the estimated sample parameters.

The reason for this is that when one of a set of perfectly correlated inputs is included in the statistical equation, the estimated effects of all are measured by the coefficient on the included variable. When all inputs are not specified in the theoretical model (as opposed to the statistical model), then the effects of the included inputs may be overestimated. That is, referring back to equation (1), if the researcher omits $X_{i1}$ from the theoretical specification, the coefficient for $X_{i2}$ is still an estimate of $(\beta_1 + \beta_2)$. However, because the theoretical specification does not include $X_{i1}$, the researcher does not realize he is overestimating the response to $X_{i2}$. A higher productivity is imputed to $X_{i2}$ than is actually justified.

Intuitively, this type of specification error would appear to be more hazardous as the number of inputs specified in the model increases. Broad categories such as land or capital are naturally presumed to reflect a general coefficient. But suppose the model is specified to isolate the effect of individual specialized additives or chemical sprays. Such inputs may be perfectly correlated with other (unspecified) inputs that are also applied to livestock or crops.

Researchers sometimes note that studies using the Cobb-Douglas function have a surprisingly common tendency to estimate returns to scale of approximately one for United States agriculture.[9] If returns to scale do tend towards unity, then this tendency could be explained by the fact that even when the model is not specified correctly, enough inputs are included to capture the total effects of each major set of inputs. Thus, even when the coefficients for particular input categories appear unrealistic because of mis-specification, the sum of the coefficients might represent a reasonable estimate of total returns.

Consider now the second specification error, that of including variables that should not be included. In such a case, the expected values of the coefficients of the superfluous variables would be zero. When such variables are included in the model, estimates of their coefficients should be negative and small, positive and small, and, on the average over many studies, close to zero. Thus, the researcher might infer that an input category is unproductive when in fact the result is due to mis-specification. The problem is to determine what should be measured and included in the statistical model.

As an example, consider input stocks and flows. While input stocks can be readily measured and included in the model, the magnitude of service flows from these stocks is in fact the appropriate measure [16, Ch. 3]. In some cases service flows *may* be perfectly correlated with amounts of other inputs. For example, in a cross-section analysis of Montana wheat farms all input service flows in wheat production will be perfectly correlated with acres of wheat grown on the farm. Whatever the farmer does on one acre, he does on all. Thus when wheat acreage is included in the production function, the resulting estimated coefficient will capture the summed effects of all service flows used on acres. *If* the service flows of an input are perfectly correlated with the quantities of one or more other inputs, then the inclusion of a stock measure of that same input amounts to a specification error.

By visualizing the problem in this manner, an explanation of an important anomaly that

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[8] Specification errors have been discussed in general by Griliches [8], Theil [24, p. 548], and Malinvaud [17, p. 71].

[9] For example, see Heady [9, p. 359] and Heady and Dillon [11, Ch. 16]. Hoch [13] has noted the problem and suggested an explanation in terms of simultaneous equation bias.

keeps reappearing in Cobb-Douglas studies of agriculture can be suggested. The productivity of farm labor has often been shown to be very low or negative—even on commercial farms [9, p. 359] [11, p. 577]. But the labor variable included in most production function studies is not the labor used (service flows) but rather the labor available for use (stocks). It is possible that labor actually expended is perfectly correlated with other inputs and is perhaps unknown even to the farmer.

Heady [10, p. 998] commented in 1946, "Another explanation for this low return may be found in the manner in which labor inputs are reported by farmers. Although the input of hired labor may be reported accurately, there may be a large bias in that of operator and family labor. The operator is prone to report twelve months labor unless he actually works off the farm. Included in this twelve months is the time actually spent at farming and also the slack months in which only a few hours of chore work are done each day. This latter limitation of the data . . . . . [suggests why] . . . . . most of the negative elasticities are for labor."

The arguments in this section provide a further support for Heady's logic. It is difficult to believe that commercial farmers consistently employ labor until its productivity is zero. On the other hand, if the stock of services exceeds the service flows actually used, then labor is an inactive constraint, to use linear programming terminology, and its marginal product would be zero. The problem is one of timeliness—at some time during the year most farmers could undoubtedly use more labor, and, if so, its marginal product is not zero at that time. But the stock measures do not lead to this conclusion!

## Management

Nothing has plagued those who estimate the Cobb-Douglas production model more than the "management problem." A short discussion here cannot serve as a substitute for the extensive discussion of the subject in the literature.[10] Rather, its purpose is to examine conditions under which exact multicollinearity may provide new interpretations.

It seems reasonable to consider management in a cross-section study in much the same manner as technology in a time-series study. The two have much in common: neither are inputs in the conventional economic sense, both have a substantial impact on output, both may vary among firms, and both are elusive to quantitative measures.

Following this reasoning, one way to add management to (1) is

(6)
$$Y_i = \beta_0 M_i X_{i1}{}^{\beta_1 + m_{i1}} X_{i2}{}^{\beta_2 + m_{i2}} \exp(\epsilon_i)$$

where the new symbols describe the level of management on farm $i$.

$M_i$ represents the "efficiency" of the manager and explains differences in the general levels of productivity among managers ("disembodied" management). $m_{i1}$ and $m_{i2}$ represent the effects of managerial abilities as they relate to individual input categories and reflect the possibilities that managers may use one type of input more efficiently than another ("embodied" management efficiency). Because the theory of production includes the assumption that the most efficient practices are used, $M_i$ might be thought of as one for the most efficient managers and fractions of one for the others.

First, consider the economic implications of (6). The $M_i$ will affect marginal and average product but will be cancelled from the cost minimizing conditions. Therefore, if $m_{i1}$ and $m_{i2}$ were equal over the sample, input use would fall on the same expansion path when all inputs are variable or if all managers were cost-minimizers. In this special case, exact multicollinearity would still hold. $M_i$ does affect the marginal product and, when all inputs are variable and decreasing returns to scale obtain, farm size. When some factors are fixed, $M_i$ would cause managers to use differing amounts of variable inputs and thus destroy exact correlation. When $m_{i1}$ and $m_{i2}$ also differ over the sample, then the expansion path will not be the same for all farms, input usage would differ for all conditions mentioned, and exact multicollinearity would not be observed. Nearly-exact multicollinearity might be common, however.

Next, to consider the statistical implications of (6), $M_i$ should be measured and included in the model or biases will result [8, p. 13]. However, $m_{i1}$ and $m_{i2}$ result from management inputs that are proportionate to the physical inputs. If such management inputs exist, they need not

[10] For a good starting point, see Johnson [14], Griliches [8], Heady and Dillon [11, p. 223], and Walters [25]. Hoch [12] and Mundlak [20] have combined cross-section and time series data and utilized dummy variables to measure the efficiency of management. One reviewer suggested that a random coefficient model might be applied to this problem.

be measured because their effects are irrevocably captured in the model. They will affect all optima and measures of returns to scale. What if (6) is wrong? If $M_i$ is in fact an illusory input, attempts to measure and include it in the production model amount to a specification error. If $m_{i1}$ and $m_{i2}$ do not exist, then the statistical model will not reflect their effects—even though the researcher imagines they exist!

The following two comments are not related to exact multicollinearity. First, to amplify the comment that $M_i$ will determine farm size when all inputs are variable and decreasing returns exist, it is perhaps useful to suggest that in practice the desire, ability, and opportunity for expansion are not perfectly correlated. Although efficient farmers may expand more readily or profitably, the desire to expand may not be perfectly correlated with efficiency. Also, expansion plans are limited by lack of opportunity or enhanced by windfall gains. Therefore, in a given sample, farm size will at best be only partially correlated with either efficiency or the desire to expand, regardless of returns to scale.

Second, the most natural way to estimate $M_i$ for the Cobb-Douglas function is to include it as an additional variable, i.e., $X_{ik} = M_i$ where $X_{ik}^{\beta_k}$ is an index measuring the management ability of the $i$th farmer. Because $M_i$ is fixed for a particular manager, the coefficient $\beta_k$ should not be included in the sum of the $\beta_j$ used to measure "returns to scale" for the individual farm (if, indeed, the concept can be termed "returns to scale" when management is fixed). The anomaly is explained by the fact that poor managers, as well as good, can (say) double output by doubling input—poor managers just need more input to achieve any particular output level.

This argument might be made clearer by proceeding as follows: let $f$ be the technical production function for the inputs used on farms (the intra-firm production function [2, 20]). Then management efficiency can be regarded as a function, $F$, that further transforms $f$ in such a manner that $y = F(f)$. ($F$ is the inter-firm function.) For the Cobb-Douglas function, the transformation $F$ might be represented by multiplying $f$ by a proportional factor $M_i = X_{ik}^{\beta_k}$. $\beta_k$ is thus a coefficient of $F$ and would not be used to measure "returns to scale" of $f$.

This type of formulation would explain the coefficient of management in an equation presented by Heady and Dillon [11, p. 225]. They added a management variable in a Cobb-Douglas function that also included land, labor, and capital inputs. The coefficients for the latter three inputs summed to 1.019 while the coefficient of management was 1.220. Swanson [23, p. 137] reports a coefficient of 0.228 for management while his other coefficients sum to 0.945. For the individual farm these studies suggest constant returns to scale for inputs other than management; for the industry they suggest the relative importance of management efficiency and perhaps potential for improvement of management through extension efforts. The degree to which the management measures used in these studies measure efficiency as defined here is not known.

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# Sparse Data, Estimational Reliability, and Risk-Efficient Decisions*

JOCK R. ANDERSON

**The minimal data required for a reasonable estimation of probability distributions is investigated through a Monte Carlo study of a rule for smoothing sparse data into cumulative distribution functions. In a set of estimated distributions, risky prospects not preferred by risk-averse decision makers can be identified and discarded.**

*Key words:* **sparse data; smoothing; reliability; risk; stochastic dominance; fertilizer.**

A PREVIOUS STUDY [3] explored the impact of different degrees of risk aversion on risk-optimal fertilizer rates in an analysis that was forced to estimate probability distributions from very sparse data. The present paper extends this work to grapple with two perceived limitations of the original study, namely the unknown reliability of the sparse-data smoothing rule employed and the recourse to arbitrary assumptions about the nature of farmers' preference functions (risk attitudes).

Accordingly this paper is organized in two parts. The first examines the reliability of the method of smoothing sparse data. Particular attention is addressed to the minimal amount of data necessary for reasonable estimation. The subtle question of what constitutes a "reasonable" estimate of a probability distribution is approached very subjectively. The second part explores how far it is possible to go in normative risk analysis without specific knowledge of decision makers' preference functions. This is accomplished through exploitation of the notions of stochastic dominance (of first, second, and third degree), and application is illustrated through the same fertilizer-wheat example [3].

## Estimational Reliability

### Generation and processing of data

It was deemed essential to be able to compare estimated distributions with their true parent distributions, so a small Monte Carlo study was conducted. Monte Carlo studies are usually constrained only by budgets for computation, but in the present case, labor-intensive hand-sketching of fractile estimates and numerical description of the smoothed cumulative distribution function (CDF) curves constrained the size of the study. Estimation employs the rule: "If a sample of $n$ observations is drawn from some distribution and arrayed in order of size, the $k$th observation is a reasonable estimate of the $k/(n+1)$ fractile of the distribution" [19, p. 104]. A smooth (less-than) CDF curve can then be drawn through the fractile estimates. This rule is nonparametric and its history (especially in conjunction with probability papers) appears to date from the work of Gumbel [9, p. 15; 10, p. 34].

Two distributions were used in this study, namely, a normal distribution and a negatively skewed Beta distribution with mode at the upper extremum. The parameters of these distributions were selected so that the generated data could be conceived as representing observed yields of a field crop with which both assessors were familiar. As crop yields are non-negative, the normal distribution with mean 30 and standard deviation 10 was truncated accordingly with insignificant impact on the general character of the distribution. The Beta distribution was specified on the range 5 through 75 with mean 57.5 and standard deviation 15.1 (shape parameters 3 and 1 [13]). Observations were generated pseudo-randomly from a source of uniformly distributed variates for the normal [4] and for the Beta [8] distributions.

For each of the two distributions, six replicates of independently drawn observations were generated for each of five sample sizes, *viz.* 3, 5, 7, 9, and 11. The 60 sets were then processed according to the quoted estimational rule and the ranked fractile estimates plotted twice preparatory to two independent hand sketches of the CDF. The sketching sheets were identified only by the number of observations and an obscure code number. Assessor 1 was told only (i) that Schlaifer's rule was reasonable, (ii) that the

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"data" were the specified wheat yields (and so were non-negative), and (iii) that (contradicting some evidence [6]) field crop yield distributions are invariably unimodal with $S$-shaped CDF's. Assessor 1 was familiar with probability calculus (including the necessity for the slope of a less-than CDF to be strictly positive). Assessor 2 (the author) knew the parent distributions but not the identification code, and attempted to follow only the instructions given to Assessor 1.

## Analysis of results

The beliefs held at the initiation of the study —beliefs that could hardly be graced as "hypotheses"—were (i) that reliability of estimation would improve progressively with sample size, (ii) that probably more than half-a-dozen observations were necessary for an estimate to be any good, and (iii) that lower moments of the estimated distributions would be estimated better than higher moments. But how is reliability appraised in estimating a whole probability distribution? One alternative not adopted would simply be to present all the graphically fitted CDF's along with the true CDF's and allow the reader to draw his own conclusions in a purely subjective fashion. Indeed, with the CDF curves sketched on transparent overlays, this subjective exercise was embarked upon, strongly reinforcing the prior beliefs (i) and (ii) with the additional reaction of surprise at the high precision (relative to expectations) of some of the estimates based on $n = 3$ and 5 and the poor precision of a few of the estimates based on $n = 9$ and 11. Since the blatant subjectivity of this observation is unlikely to be convincing, some summary indicators are now suggested.

Concern in assessing estimational reliability is with the "goodness-of-fit" of an estimated distribution with its parent. However, available goodness-of-fit tests such as the Chi-square and Kolmogorov tests [5] are applicable to testing hypotheses about sample observations from a specified distribution and so cannot be used directly in the present instance. Both the mentioned nonparametric tests have the feature, virtuous in the present context, that the *whole* distribution is considered in the test. To exploit this feature, variations on each of the tests are applied to the estimated distributions.

The *Chi-square* test of goodness of fit is simple to use and appropriate when many data are available. It was used in the study by generating variates from each of the estimated distributions and calculating a test statistic for the null hypothesis that each set of generated variates came from the true parent distribution. Because of the irregular shape of many of the estimated CDF curves, the procedure adopted was to approximate each CDF with 20 linear segments spanning equal probabilities. The variates were then generated by an inverse CDF transformation from uniform pseudo-random variates via the linear-segmented estimated CDF's. The test statistic was based on 20 equal-probability intervals from the parent distribution (i.e., 19 degrees of freedom). In each case 300 variates were generated, and to sharpen contrasts in the comparisons, the same sequence of uniform pseudo-random variates was repeated on every occasion. One critical value ($\alpha = 0.05$) is 30.14. The bulk of test statistics greatly exceed this conventional critical value, indicating that in most cases the hypothesis that the generated variates actually came from the parent distribution would be rejected. Since it is known that in fact they did not (they came from the estimated distributions), this result should occasion little surprise. Figure 1 depicts the influences of sample size, type of distribution, and assessor on the precision of estimation.

The data of Figure 1 seem best interpreted graphically. It may appear that a formal test of the mentioned influences should be conducted through, say, an analysis of variance of the Chi-square statistics. However, this would focus attention only on the differences between mean Chi-square statistics in each category, whereas the distinctive and most important feature of the data is the spread of the statistics—especially within each sample size category. The author's interpretation of the results exhibited in Figure 1 is as follows:

1. Estimation of distributions from sparse data is an imperfect business.
2. The probability of making very poor estimates decreases as sample size increases from 3 to 11.
3. Even with sample size as small as 3 or 5, there is about 0.5 probability of making a "good" estimate of an unknown probability distribution ("good" here indicated arbitrarily by a Chi-square test statistic $< 200$).
4. The individuality of the subjective smoothing process leads to some differences between estimates of different assessors, but these differences diminish with sample size, virtually disappearing by $n = 11$.

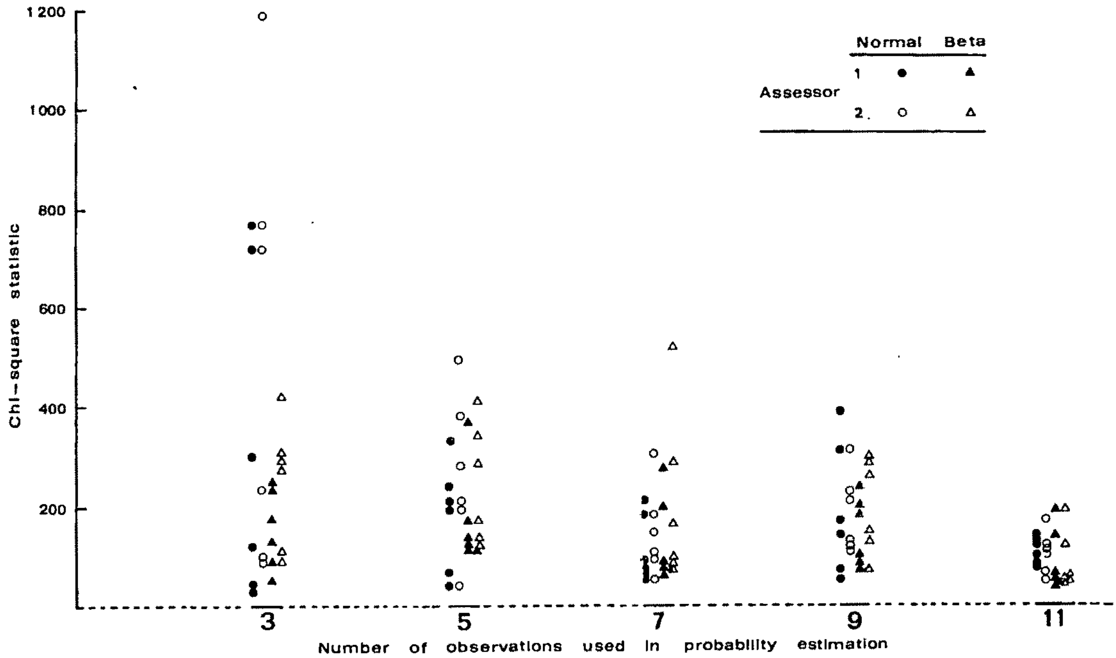


**Figure 1. Chi-square measure of goodness of fit and sample size for two assessors and two distributions**

5. There is little difference between the results for the two distributions except for fewer really "bad" estimates in the Beta case at $n = 3$.
6. Even with nine or more observations, estimates may be very imprecise.

The next measure of closeness-of-fit employed has no known sampling distribution. It is analogous to the statistic for the *Kolmogorov test* of goodness-of-fit and is presented only as an additional indicator to supplement the foregoing results. The measure proposed is the maximal absolute vertical difference (in cumulative probability) between the estimated CDF curve and the parent CDF curve. The use of the (smooth) CDF curve contrasts with the use of the (step) empirical distribution function in the Kolmogorov test.

The statistics are presented graphically in Figure 2 in a style directly analogous to that used in Figure 1. The author considers that these results generally support the foregoing interpretations of the Chi-square results. Again, a prime reason for presenting the results in this manner is to facilitate the reader's own interpretation since this topic appears to be intrinsically subjective.

A result not anticipated but more apparent from Figure 2 than from Figure 1 is the superiority of estimation of the Beta distribution relative to the normal distribution. The author is at a loss to offer an explanation for this since the sketching instructions particularly emphasized *S*-shaped CDF's, and the parent Beta was convex throughout. However, it is comforting to note that the estimational method does not collapse when distributions are markedly nonnormal.

Decision analysts may make use of *moments* of an assessed distribution rather than of the distribution itself, so there is some pertinence in asking how reliable are moments derived from distributions fitted to sparse data [3]. It must be observed that the techniques for estimating the first few moments are well developed, yielding (variously) consistent, unbiased, minimal variance, or maximum likelihood estimates of population parameters. However, especially for moments higher than the first, such estimation would be applied with little confidence to data situations described here as sparse. Estimation of moments from smoothed sparse data might thus be described as a potential best-bet procedure of last resort.

The first four moments were computed from the midpoints of the 20 equal-probability intervals of each of the estimated distributions. Broadly, it can be commented that estimation improved with sample size, was not strongly influenced by either distribution type or assessor,

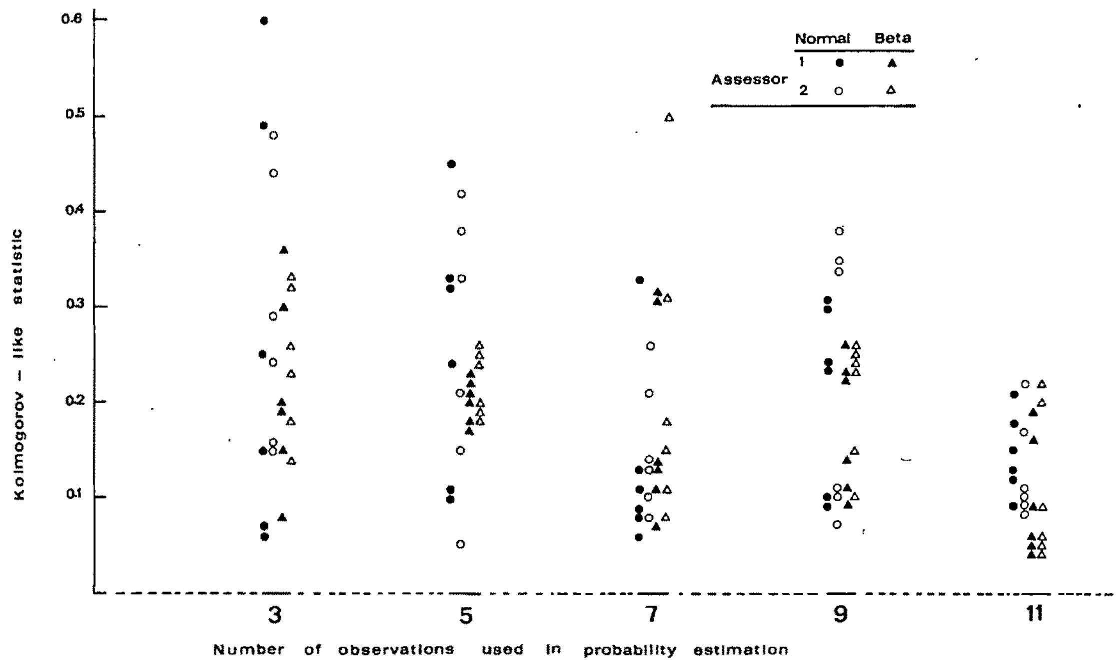


Figure 2. Kolmogorov-like measure of goodness of fit and sample size for two assessors and two distributions

and deteriorated progressively for the second and higher moments. Table 1, which summarizes the pattern of precision attained, reports the number of the six estimates (derived from the graphical CDF's of Assessor 1) of various parameters which fall outside specified arbitrary bounds of the true values. The corresponding results for Assessor 2 are almost identical. A lower score indicates a closer fit.

The data of Table 1 suggest that moments derived from sparse-data CDF's are not notably accurate, especially for higher moments, and the situation does not improve dramatically with increasing size of sample over the range examined. While these indirect estimates were often very similar to, they sometimes differed substantially from conventional unbiased sample estimates of the population parameters.[1]

[1] For $n$ observations $X_1, X_2, \ldots X_n$, $Z_j = \sum_{i=1}^{n} X_i^j$, $j = 1, 2, \ldots 4$,
$S_2 = Z_2 - Z_1^2/n$, $S_3 = Z_3 - 3Z_1 Z_2/n + 2Z_1/n^2$,
$S_4 = Z_4 - 4Z_1 Z_3/n + 6Z_1^2 Z_2/n^2 - 3Z_1^4/n^3$,
$\hat{\mu} = Z_1/n$, $\hat{\sigma}^2 = [S_2/(n-1)]$,
$\hat{\mu}_3 = n S_3/[(n-1)(n-2)]$,

Table 1. Frequency (out of six) of indirect estimates[a] outside specified bounds

| | | Sample size | | | | |
|---|---|---|---|---|---|---|
| Parameter and Bounds | Distribution[b] | 3 | 5 | 7 | 9 | 11 |
| Mean $\mu \pm .1(.2)\mu$[c] | $N$ | 4(2) | 4(3) | 1(0) | 3(2) | 2(0) |
| | $B$ | 3(1) | 1(0) | 3(0) | 0(0) | 1(0) |
| Median $M \pm .1(.2)M$ | $N$ | 4(2) | 4(1) | 1(0) | 3(1) | 1(0) |
| | $B$ | 3(2) | 4(0) | 3(1) | 3(1) | 2(0) |
| Standard deviation $\pm .1(.2)\sigma$ | $N$ | 4(2) | 4(3) | 4(3) | 4(2) | 5(3) |
| | $B$ | 2(0) | 4(1) | 3(3) | 2(2) | 3(3) |
| Skewness[d] $\alpha_3 \pm .2(.4)\alpha_3$ | $N$ | 5(1) | 5(3) | 4(4) | 5(4) | 4(3) |
| | $B$ | 3(1) | 3(1) | 4(2) | 4(2) | 3(1) |

[a] Based on CDF's smoothed by Assessor 1.
[b] $N$ denotes Normal and $B$ denotes Beta.
[c] Frequencies are presented for a narrow and (in parentheses) a wider range, the width of which is indicated by the factor in parentheses. Relatively good estimates are identified by relatively low frequencies.
[d] $\alpha_3 = \mu_3/\sigma^3$ where $\mu_3$ is the third moment.

A comparison of such estimates is reported in Table 2. With only six comparisons in each cell, not too much can be made of the statistical significance of results. Indeed the sign test predicated on a null hypothesis that conventional and indirect estimates are equally good is a crude test and only approximately valid since both estimates in each comparison are based on the same set of generated observations. Closeness is judged in terms of the absolute deviation between known parameter and corresponding sample estimate.

The author's impressions after careful review of Table 2 and the data underlying it[2] are that *for sparse data* situations the indirect method is generally better than the conventional unbiased estimation of moments *except for* estimation of the mean and for estimation of the standard deviation with more than nine observations. The "price one pays" for improved estimates is a more tedious estimational procedure.

### Summary on estimational reliability

An analyst would not attempt to estimate a probability distribution from a mere handful of data by choice, but when faced with the situation, as he too often is, he must either throw up his hands in despair and await more data or make the best of the unfortunate circumstance. The limited results reviewed here suggest that, apart from resorting to purely subjective assessment, reasonable progress can be made in probability estimation by use of the simple smoothing rule and procedure advocated.

The chance of success increases with the number of data available, and results obtained by different assessors will probably be similar. However, there is no guarantee of precision, especially of the derived higher moments, even as the number of observations reaches a possibly "decent" total of 10 or so. *C'est la vie!*

$\hat{\mu}_4 = n[(n+1)S_4 - 3(n-1)S_2^2/n]/[(n-1)(n-2)(n-3)]$, $\hat{\alpha}_3 = \hat{\mu}_3/\hat{\sigma}^3$, $\hat{\alpha}_4 = \hat{\mu}_4/\hat{\sigma}^4$; see [20, pp. 200–220].

[2] Also reviewed were the unreported results on comparing estimates of kurtosis, $\alpha_4$, for which the unbiased estimate was computed as defined in foonote 1 except when $n = 3$, $\hat{\alpha}_4 = [S_4/n]/\hat{\sigma}^4$.

## Risk-Efficient Decisions

### Previous work

Attention is now turned to the second perceived limitation of the previous study [3] of risky choice of levels of nitrogen ($N$) and phosphorous ($P$) fertilizers used on non-irrigated wheat. This limitation relates to the assumptions made about farmers' attitudes toward risk. For economy of explanation, no new data or assumptions are presently introduced.

Briefly, data were available from $N$-$P$ response experiments conducted in each of these successive years at the same site. Response functions estimated for individual years were used to predict response at each design point of a complete $6 \times 6$ factorial in $N$ and $P$. The predictions at

Table 2. Frequency (out of six) of occasions when unbiased conventional statistics were closer to the true parameters than were the indirect estimates of the specified assessor

| Parameter[a] | Assessor | Distribution[a] | Sample size 3 | 5 | 7 | 9 | 11 | Marginal frequency (out of 30) |
|---|---|---|---|---|---|---|---|---|
| $\mu$ | 1 | $N$ | 5[b] | 2 | 3 | 4 | 2 | 16 |
| | | $B$ | 4 | 3 | 0[c] | 2 | 3 | 12 |
| | 2 | $N$ | 4 | 3 | 2 | 3 | 4 | 16 |
| | | $B$ | 4 | 3 | 3 | 2 | 5[b] | 17 |
| $\sigma$ | 1 | $N$ | 0[c] | 4 | 3 | 2 | 5[b] | 14 |
| | | $B$ | 1[c] | 3 | 2 | 2 | 1[c] | 9 |
| | 2 | $N$ | 2 | 1[c] | 3 | 0[c] | 4 | 10 |
| | | $B$ | 1[c] | 2 | 4 | 4 | 3 | 14 |
| $\alpha_3$ | 1 | $N$ | 0[c] | 0[c] | 3 | 3 | 2 | 8 |
| | | $B$ | 0[c] | 3 | 2 | 0[c] | 0[c] | 5 |
| | 2 | $N$ | 0[c] | 0[c] | 4 | 3 | 1[c] | 8 |
| | | $B$ | 0[c] | 3 | 2 | 1[c] | 1[c] | 7 |

[a] Symbols are as defined for Table 1.
[b] Conventional is "significantly better" than the smoothed estimate in a two-tailed sign test at the significance level of .22.
[c] Conventional is "significantly worse" than the smoothed estimate in the same sign test.

each design point were smoothed into yield CDF's using the procedure discussed above.[3] These are the data subjected to further analysis here.

The previous study involved describing these distributions in terms of moments and relating these functionally to levels of $N$ and $P$. Finally, what were called "risk-optimal" rates were determined under various assumptions about an expected-utility objective function specified in terms of moments of distributions of farm profit derived from the yield distributions. These procedures must be regarded as imperfect in at least two ways. First, if distributions are not normal and if preferences are not polynomial, moment descriptions of distributions and moments as arguments of preference functions are, at best, approximations. Second, since individuals generally differ in their attitudes toward risk, it is not clear how preference functions should be specified to reach any generality about the impact of risk—in the absence of definite knowledge of attitudes among the population.

Such knowledge is seldom if ever available, hence it is important to learn how far risky planning can go in the absence of such specific knowledge. The intention here is to illustrate some useful procedures which allow analysis of risky decisions to go quite a long way. This will lead to identification of "risk-efficient" actions (fertilizer rates), in contrast to "risk-optimal" actions which depend on particular (and individual) preferences.

## Stochastic dominance

In the literature of the pre-1960's, a risky prospect was said to dominate another stochastically if the consequences of the dominant act were at least as preferred as the dominated act for all possible states and were preferred for at least one state. This concept was formalized [17] and extended to accommodate risk aversion [11, 12] and an aspect of decreasing risk aversion [22] through a series of rules for ordering risky prospects based on CDF's or functions derived from CDF's.

Three ordering rules are operational and, while extensions to more stringent rules are obvious, the behavioral implications are too shaky for further such rules to be generally useful. The three rules relate to first-degree ($FSD$), second-degree ($SSD$), and third-degree ($TSD$) stochastic dominance. Assume that preference is a function of a single uncertain quantity, $x$, encoded in $U(x)$, and write the $i$th derivative with respect to $x$ as $U_i(x)$. Consider two prospects involving the continuous random variable $x$, $a \leqslant x \leqslant b$, with frequency functions of $f(x)$ and $g(x)$. Define for $f$, and analogously for $g$, $F_0(x) = f(x)$ and $F_n(R) = \int_a^R F_{n-1}(x)\ dx$, $n \geqslant 1$, so that $F_1(R)$ is the CDF of $f(x)$. Then the behavioral (preference) assumptions and the corresponding ordering rules for $f$ to dominate $g$ at the indicated degree can be summarized as:

| | | |
|---|---|---|
| $FSD$ | $U_1(x) > 0$ | $F_1(x) \leqslant G_1(x)$ |
| $SSD$ | $U_1(x) > 0$ | $F_2(x) \leqslant G_2(x)$ |
| (risk aversion) | $U_2(x) < 0$ | |
| $TSD$ | $U_1(x) > 0$ | $F_3(x) \leqslant G_3(x)$ |
| (implied by decreasing risk aversion as wealth increases) | $U_2(x) < 0$ | $F_2(b) \leqslant G_2(b)$ |
| | $U_3(x) > 0$ | |

where here only, $\leqslant$ is read as "less than or equal to for all possible $x$ with strict inequality holding for at least one value of $x$." This terse presentation does not highlight the importance of the lower tails and the means of distributions in dominance reviews. For $f$ to dominate $g$ in any sense defined above, it is necessary that the lowest possible value of $f$ not be smaller than the lowest value of $g$ and the mean of $f$ not be smaller than the mean of $g$.[4]

Generally, the set of risky prospects found not to be dominated (i.e., the stochastically efficient set) according to each rule will be smaller, the higher is the degree (i.e., the more restrictive are the behavioral assumptions). $FSD$ seems quite uncontroversial. $SSD$ assumes only

[3] It has been noted [7] that use of predictions rather than actual data probably leads to estimates of variance that are biased downwards. However, the predictions were used because the experimental rates varied from year to year and hence interpolation was necessary.

[4] The focus of dominance criteria on the left-hand portions of distributions accords with the intuition of many analysts but perhaps does not go far enough. Robert T. Masson has suggested to me the development of dominance criteria that ignore outcomes above, say, the mean. However, this seems difficult to defend from modern risk theory and in my limited experience would exert little influence in empirical orderings. Relatedly, Stanley R. Johnson has suggested to me that for similar reasons my assessment of estimational reliability should give greater weight to comparisons of the left-hand portions of CDF's. My limited attention to this question (including use of $FSD$ checks) for the data discussed early in this paper led me to the conclusion that the results presented would not be altered significantly by shifting assessment from the whole to the left-hand portion of distributions.

that decision makers are averse to risk and as such seems an acceptable presumption, given the conventional wisdom on risk and its importance in farming. *TSD* is more controversial but is defensible on the grounds that $U_3(x) > 0$ is implied by the requirement (a speculation strongly supported by intuition [16]) that risk aversion diminishes as a decision maker becomes wealthier.

Application of the ordering rules to empirical problems is demanding by the required estimation of whole distributions. Difficulties arise through the required evaluation (and comparison) of successive integrals for what will generally be many risky prospects. The latter difficulties are minimized for discrete distributions and maximized for continuous theoretical distributions such as the normal. This analyst's pragmatic solution to these difficulties (elaborated in [2]) has been to concentrate on approximation of continuous distributions through (an arbitrary but ample number of) linear segments to describe CDF's. Implementation of the ordering rules then becomes a fairly straightforward task well-suited to machine computation.

## Identifying risk-efficient fertilizer rates

The data are the 36 probability distributions of wheat yield previously estimated [3]. The fertilizer levels are $N = 0, 20, 40, 60, 80, 100$ lb/ac and $P = 0, 8, 16, 24, 32, 40$ lb/ac. The distributions, which reflect between-year variability, were described by 20 linear segments of equal span of cumulative probability. The yield distributions were transformed to return distributions by the linear expression $R_{ijk} = p_y Y_{ijk} - p_n N_i - p_p P_j$, where $R$ denotes return, $Y$ denotes yield, $N$ denotes nitrogen applied, and $P$ denotes elemental phosphorus applied, all per unit area; $p_y$, $p_n$, and $p_p$ are the respective unit prices of $Y$, $N$, and $P$; and the subscripts $ijk$ denote respectively the $i$th level of $N$, the $j$th level of $P$, and the $k$th fractile. Prices assumed are as previously reported [3]. Fixed costs are not included as they have no influence on the determination of stochastic efficiency.

The outlined procedure [2] for reviewing stochastic dominance was applied to these 36 discrete acts. The results are most easily overviewed in Table 3 with rows and columns defined by rates of $N$ and $P$ and the elements by the degree of stochastic efficiency, where zero denotes dominated in the sense of *FSD*. A combination of fertilizers whose distribution of returns is not dominated by any other in the

Table 3. Degree of stochastic efficiency[a] of specified *N-P* combinations

| *N* (lb/ac) | *P* (lb/ac) 0 | 8 | 16 | 24 | 32 | 40 |
|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 3[b] | 3[b] | 3[b] | 3[b] |
| 20 | 0 | 0 | 0 | 3[b] | 3[b] | 1[b] |
| 40 | 0 | 0 | 1 | 3[b] | 1 | 1 |
| 60 | 0 | 0 | 0 | 1 | 1 | 1 |
| 80 | 0 | 0 | 0 | 1 | 1 | 1 |
| 100 | 0 | 0 | 0 | 0 | 1 | 1 |

[a] A prospect is here described as stochastically efficient of degree $i(=1,2,3)$ if it is not dominated by any other prospect considered at that degree. The progressively more restrictive orderings mean that for the tabulated degrees 3 implies 2, and 2 implies 1. The zero degree here describes a prospect dominated in the sense of *FSD*.

[b] Members of the mean-variance-efficient set.

sense of *FSD* is defined as being stochastically efficient of first degree (*FSE*) and is indicated by an integer $\geqslant 1$ in Table 3. Combinations that are first-degree efficient become candidates for *SSD* review, and those that are not dominated in this sense are efficient of degree two (*SSE*) and would be indicated by an integer $\geqslant 2$ and in turn become candidates for *TSD* review. Those not dominated in the sense of *TSD* are third-degree efficient (*TSE*) and are indicated by the integer 3. In this case the *SSE* and *TSE* sets are identical so that no "2" entries appear in Table 3. For simplicity, the *SSE* and *TSE* combinations shall be referred to here as "risk-efficient."

These results indicate a fairly consistent pattern: in this case relating to crop response on a red-brown earth, a necessary condition for stochastic efficiency of any order (non-zero entries in Table 3) is a reasonable dose of phosphorus. Nitrogen is again indicated as being rather risky since most of the risk-efficient combinations involve zero levels of $N$, and the highest risk-efficient rate of $N$ is 40 lb/ac in this non-irrigated situation. Within the risk-efficient set, choice of fertilizer rate properly depends upon the risk preferences of individual farmers.

Given the consistent pattern of risk-efficient rates, it seems reasonable to interpolate[5] within

[5] Interpolation among such results would be difficult if either the pattern was apparently discontinuous or if the interpolation interval was quite wide. The alternative interpolation (pursued in [2]) that is more in conformity with conventional response analysis is to interpolate yield distributions for levels of variable factors between actual observations.

the set. Making such an interpolation suggests that the risk-optimal rates computed after resorting to specific assumptions about risk preference functions (reported in [3]) fall within the efficient range. This should not be surprising, except that the specifically risk-optimal rates were computed by an approximate procedure that used only the first two moments of the yield distributions.

The pattern and size of stochastically efficient sets are empirical phenomena about which it is impossible to generalize. Here *TSD* did not eliminate any of the acts efficient under *SSD*, but in other cases [2] the *TSD*-efficient set is rather smaller than the *SSD*-efficient set. Here the risk-efficient range might be regarded as being somewhat confined (7 efficient acts out of 36) whereas in other cases (e.g., *N* on rice [2]) the risk-efficient range is quite wide (e.g., approximately 0 to 70 lb/ac *N*). Although extremely unlikely, it would be possible for only one combination of variable factors to be risk efficient.

However such results appear, they are bound to be useful in an extension context. If the range is tight, recommendations can be rather precise. If the range is wide and the average profit function fairly flat, attention can be focused on recommendations that minimize risk subject to other constraints. If the range is wide and average profits and risk are fairly sensitive to varying inputs, then general advice should indeed be general and imprecise, and individual advice should be tailored to individual circumstances including risk attitudes.

The concepts of stochastic dominance were developed to avoid the theoretical shortcomings of alternative ordering criteria such as those based on the mean-variance (*E-V*) attributes of risky prospects. However, the use of moments (including *E-V*) has recently been defended from several pragmatic points of view [1, 18, 21]. An important practical question is to enquire as to the similarity of risk-efficient sets under stochastic dominance and, say, *E-V* efficient sets.[6] Experience in portfolio analysis [14, 15] suggests that these sets may be quite similar. The present case supports this contention about similarity—as is indicated in Table 3 by the superscripted elements. In fact, only one of the eight *E-V* efficient combinations was not also a member of the risk-efficient set. Clearly in this particular case, the additional cost and complexity of reviewing stochastic dominance hardly compensates for the gain in more acceptable conceptual and theoretical backing.

## Conclusion

To the extent that relevant probability distributions can be specified, analysis of risky decisions confronting farmers can proceed a fair way without assuming anything very controversial about their attitudes toward risk.[7] Such analysis is computationally burdensome when many risky prospects must be reviewed but, under some simplifying assumptions, procedures adaptable to machine computation can be evolved.

The key question in appraising the practicability of any analysis of risk, including that discussed here, is the ability to estimate probability distributions in data situations that will almost inevitably be inadequate and sparse. The results discussed first in this paper suggest that the situation is not completely hopeless but that the advocated estimational procedure is no panacea. Analysis of risk in agricultural economics may be important, but it is an intrinsically risky business.

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[6] A prospect is *E-V* efficient if it is not dominated by any other prospect considered, in the *E-V* sense. Distribution $f$ dominates $g$ in the *E-V* sense if $E_f \geqslant E_g$ and $V_f \leqslant V_g$ with at least one of the strict inequalities holding.

[7] This conclusion ignores the issue of differences between operative and perceived probability distributions. Insofar as farmers' perceptions match the distributions specified in analysis, analysis of risk efficiency through stochastic dominance rules will be descriptive and normative.

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# Applying Theory of Signal Detection in Marketing: Product Development and Evaluation

ROBERT C. ANGUS AND TERRY C. DANIEL

**The theory of signal detectability and its associated methodology have been extended by psychologists for application to the evaluation of human perceptual judgments. The application of signal detection procedures are illustrated through a brief description of an experiment evaluating different ice cream products.**

***Key words:*** **theory of signal detectability; product development.**

THEORY OF SIGNAL DETECTABILITY (TSD) was originally developed in the context of electrical engineering problems associated with detecting electromagnetic signals in the presence of noise. An important contribution of this theory was formal recognition of the interaction of the sensitivity of the receiving device (its ability to sense and discriminate appropriate stimulus energies) and the decision criteria that determine reactions of the receiver to any given stimulus input. The theory and its associated methodology have been extended and modified by psychologists in recent years for application to the evaluation of human perceptual judgments. A thorough review of the historical evolution of the theory in this context has been presented by John Swets [4]. The success of signal detection theory analyses in a large number of human perceptual judgment situations suggests that the theory may be useful in evaluating consumer reactions to a variety of products. A brief description of an experiment evaluating different ice cream products is presented below to illustrate the application of signal detection procedures.

The objective was to determine the extent to which a taste-testing panel could discern richness of ice cream products and to investigate how fat level, flavor, and overrun (density of mix) influenced their judgment. The three factors (fat, flavor, and overrun) were held at high, medium, and low levels, resulting in 27 different ice cream mixes. Members of the panel were asked to rate each mix independently as rich or not rich.

This single-stimulus procedure is known to be susceptible to the confounding influence of response bias [6, p. 18]. An observer may consistently judge the high fat, high flavor, low overrun mix as being rich. However, this observer may also judge most of the other mixes as rich. These judgments may indicate that the observer has a relatively low judgment criterion for richness. The meaning of an observer's judgments for one mix must be evaluated in terms of their relationship to the observers' judgments for other mixes. TSD is helpful in this situation. It offers a means of distinguishing an observer's judgment criteria from his ability to perceive differences in richness.

## The Decision Model

The classical signal detection approach requires an observer to judge whether a signal is present or absent. The signal stimulus was usually defined in physical terms. A correct decision, a hit, occurred if the observer identified the signal when it was present. Identification of a signal when it was not present was called a false alarm.

The ability of an observer to detect a signal from noise is described by the observer's receiver operating characteristics (*ROC*). The *ROC* is a bivariate function relating an observer's hit rate and false alarm rate. The *ROC* provides an estimate of the distance between the hypothetical noise distribution and the signal-plus-noise distribution. It is formulated by obtaining hit rates and false alarm rates for a number of decision criteria levels.

The ice cream mix experiment requires a contemporary application of TSD. In this case, there is no clear cut definition of richness as applied to a specific ice cream mix. Thus, there is no *a priori* physical definition for richness, and no reason to call a response a hit or a false alarm. For this application, the decision model can be illustrated by plotting the probability, given a specific mix, over a dimension of perceived richness, Figure 1.

When an individual samples a specific ice cream mix, his perception of that mix may be represented as a value on a hypothetical rich-

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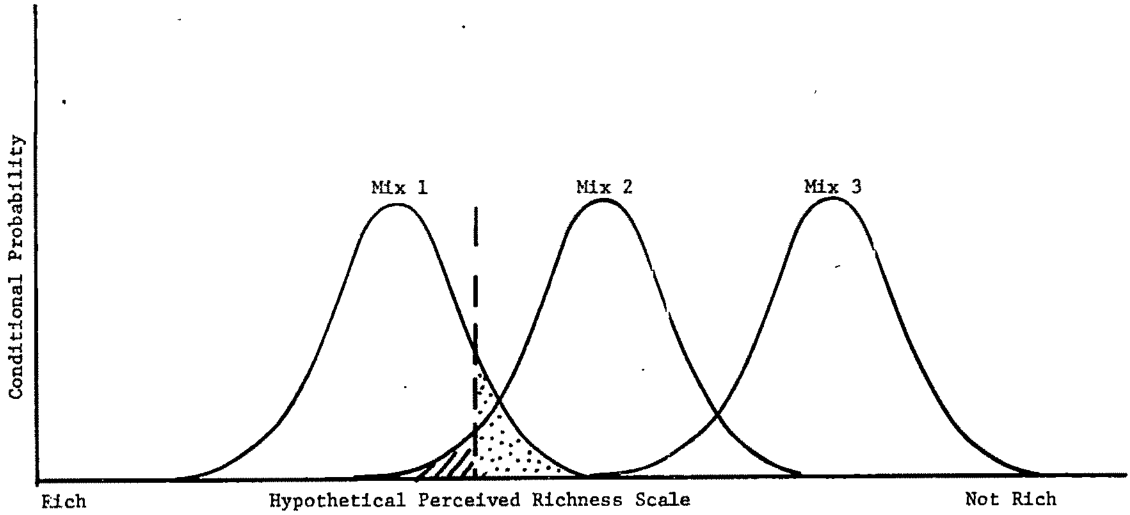


**Figure 1. Theory of Signal Detection Model**

ness scale. In repeated sampling of the same mix the richness values are assumed to be distributed normally. The dispersion is introduced by variations in the observer's perceptual process and/or by variability in the physical properties of an ice cream mix. Specific mixes may be represented by probability distributions at different locations on the richness scale. The dashed line represents a criterion for a judgment of "rich" by an observer. Perceived richness values to the left of this line are judged rich, and values to the right are judged not-rich.

Overlap of the distribution represents opportunities for confusion. In general Figure 1 represents an easy discrimination because the overlapping areas are small. Shifts in the location of the judgment criterion (dashed line) toward the rich end of the scale would result in fewer "rich" judgments for mix 2. At the same time, however, fewer mix 1 samples would be judged as "rich." Thus, wherever the decision criterion is located, differences in judgments for mix 1 and mix 2 will depend upon the distance between the two perceived richness distributions.

## Method of Analysis

Members of the taste panel reported their decisions as to the richness of an ice cream sample on a ten point certainty scale, Table 1. A judgment of nine meant that the subject was absolutely certain the mix was rich. Absolutely certain decisions implied a subject used his most rigorous decision criterion. A rating of four implied the subject guessed and that the mix could be judged rich only under less rigorous criteria. Column two of Table 1 shows the frequency of occurrence of each score for the mix with medium levels of fat, overrun, and flavor (*MMM*).

Column three, Table 1, simply cumulates the proportion of responses from the bottom. Each cumulative probability has been transformed into a $Z$ score by use of the cumulative standard normal distribution, Column 4. The same procedure is followed for the mix with low levels of fat, overrun, and flavor (*LLL*). In the authors' experiments the *MMM* mix was arbitrarily selected as a standard of comparison [1].

A plot of the $Z$ transformations of *MMM* against themselves results in the 45° diagonal, Figure 2. A plot of the $Z$ transformations of *MMM*, Column 4, Table 1, against those for *LLL*, Column 7, Table 1, is represented by the line labeled *LLL*. The distance of the *LLL* line from the diagonal indicates the degree of discrimination. The further *LLL* is from *MMM*, the greater the degree of discrimination. Functions falling above the positive diagonal indicate that the compared product is perceived as less rich than *MMM* while those below the diagonal would be perceived as richer than *MMM*. Note that placing *MMM* on the abcisa and the compared stimulus (*LLL*) on the ordinance would simply reverse the sign of the relationship.

Several methods of measuring the distance of lines such as *LLL* from the diagonal have been used. The most frequently applied distance statistic, $\underline{d}'$, is measured along the *LLL* ("false alarm") axis to the intercept of the function. The $\underline{d}'$ value for the *LLL* function is indicated in the upper-right corner of Figure 2. Another

**Table 1. Data illustrating TSD computations**

| Certainty Level | Medium, Medium, Medium Mix Frequency | Cumulative Proportion | Z Trans-formation | Low, Low, Low Mix Frequency | Cumulative Proportion | Z Trans-formation |
|---|---|---|---|---|---|---|
| 0 Certainty Not Rich | 1 | 1.000 | 2.502 | 5 | 1.000 | 2.502 |
| 1 | 3 | .979 | 2.038 | 8 | .896 | 1.257 |
| 2 | 4 | .917 | 1.382 | 6 | .729 | .608 |
| 3 | 3 | .833 | .965 | 7 | .604 | .262 |
| 4 | 4 | .771 | .739 | 4 | .458 | — .104 |
| 5 | 4 | .688 | .486 | 6 | .375 | — .316 |
| 6 | 7 | .604 | .262 | 8 | .250 | — .672 |
| 7 | 11 | .458 | — .104 | 4 | .083 | —1.382 |
| 8 | 5 | .229 | — .739 | 0 | .000 | —2.502 |
| 9 Certainty Rich | 6 | .125 | —1.149 | 0 | .000 | —2.502 |
| | 48 | | | 48 | | |
| | | | .7102 | | | — .3166 |

$$\underline{d}_m = \sum_{i=1} Z_{mmm}/N_c - 1 - \sum_{i=1} Z_{lll}/N_c - 1 = \sum_{i=1} \underline{d}_i/N_c - 1 \quad \underline{d}_m = .7102 - (-.3166) = 1.0268$$

frequently used statistic, $\underline{d}_s$, is the distance from the positive diagonal at the intercept of the function with the negative diagonal as indicated in Figure 2 for *LLL*.

A third distance metric, $\underline{d}_m$, is simply the mean of the $Z$ scores for the standard of comparison (*MMM*) minus the mean $Z$ score for the mix which is compared (*LLL*), as illustrated by Table 1. Note the difference in $Z$ scores, for

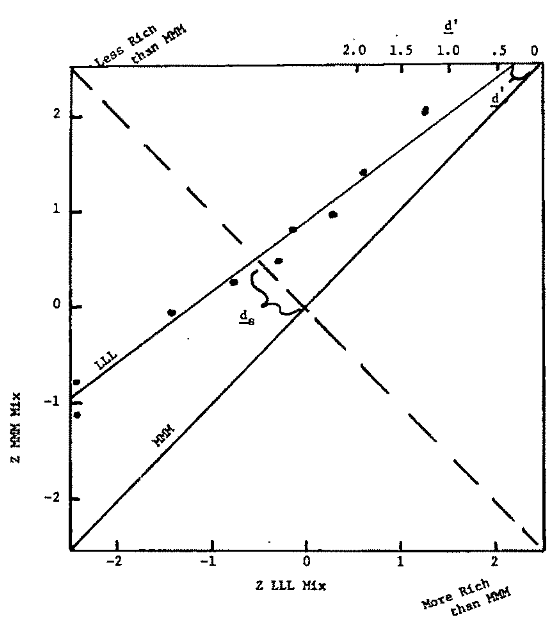


**Figure 2. Normalized "*ROC*" functions**

the zero certainty score ($d_o$) is zero. This is because the $Z$'s are transforms of the cumulative probability which must sum to one. Standard deviations and standard errors of $\underline{d}_m$ may also be computed. In any case, the larger the $\underline{d}_m$ value in absolute terms, the greater the observer's ability to distinguish between an ice cream mix and the standard, *MMM*.

Each of the measures, $\underline{d}'$, $\underline{d}_s$, and $\underline{d}_m$, has its particular advantages. The $\underline{d}_m$ was used here because it is least affected by the slope of the *ROC* and is easily computed from the actual $Z$ values obtained.

Detailed explanations of the computational procedures for TSD are presented by a number of sources such as Green and Swets [2], Swets [4], and Wheeler *et al.* [6]. The brief description presented above is sufficient to illustrate how the TSD technique eliminates bias due to the judgment criterion. Observers' judgments of the richness of products are a combined function of their perception of "richness" in the product as well as their judgment criteria. Perception and judgment criterion effects are confounded in the simple rating responses reported by the observers. Measures of product richness that are based directly upon reported ratings, such as the mean rating, fail to distinguish between perceptual effects of the product and judgment or response criteria adopted by the observer. The $\underline{d}_m$ is a function of perceived richness only. Both perception and judgment criterion effects are

confounded in a single rating response. Therefore, an analysis of variance of simple mean ratings fails to separate perception from judgment criterion.

This argument can be illustrated by the following hypothetical situation. Consider two taste panels, each of which is atypical of the population in terms of judgment criterion. For example, a home economist group used in a pretest of the ice cream experiment generally rated the high fat, low overrun, and low flavor mix (*HLL*) as being more than fairly certain rich, a rating of eight. A second test group rated the same mix as fairly certain not rich, a rating of two. It appears from the ratings that the home economist group perceived the mix as being richer than did the other group. However, it is possible that the difference was due entirely to differences in judgment criteria and that both panels perceived the mix as equally rich. This appears to be the case because the home economist group rarely rated any mix below fairly certain rich, that is almost all mixes were rated as eight or nine. Conversely, the second group rarely rated any of the mixes above just guessing not rich, a rating of four. Since the signal detection index expresses differences in ratings of the *HLL* mix from ratings of the *MMM* mix by the same group, this judgment bias is eliminated and the $\underline{d}_m$ values were found to be essentially the same for the two groups. This illustrates the importance of transforming the ratings to signal detection metrics, $\underline{d}_m$, rather than accepting ratings at face value.

The example above illustrates how differences in criteria, by changing the origin of rating responses, can make comparisons of raw rating scores ambiguous. A similar problem arises if one panel uses an expanded rating scale. The $Z$ transformation in the TSD analysis standardizes the units for the $\underline{d}_m$ metric. Other techniques may be used to accomplish standardization of rating scores, but these require substantial expansion of the number of judgments per stimulus per subject. Another advantage of the TSD procedures is that the resultant measures, e.g., $\underline{d}_m$, are systematically derived from a theoretical model of psychophysical judgment.

The results of the experiment with the 27 ice cream mixes are summarized in Figure 3. The numbers on the graphs at each mix represent current ingredient costs in dollars per gallon of

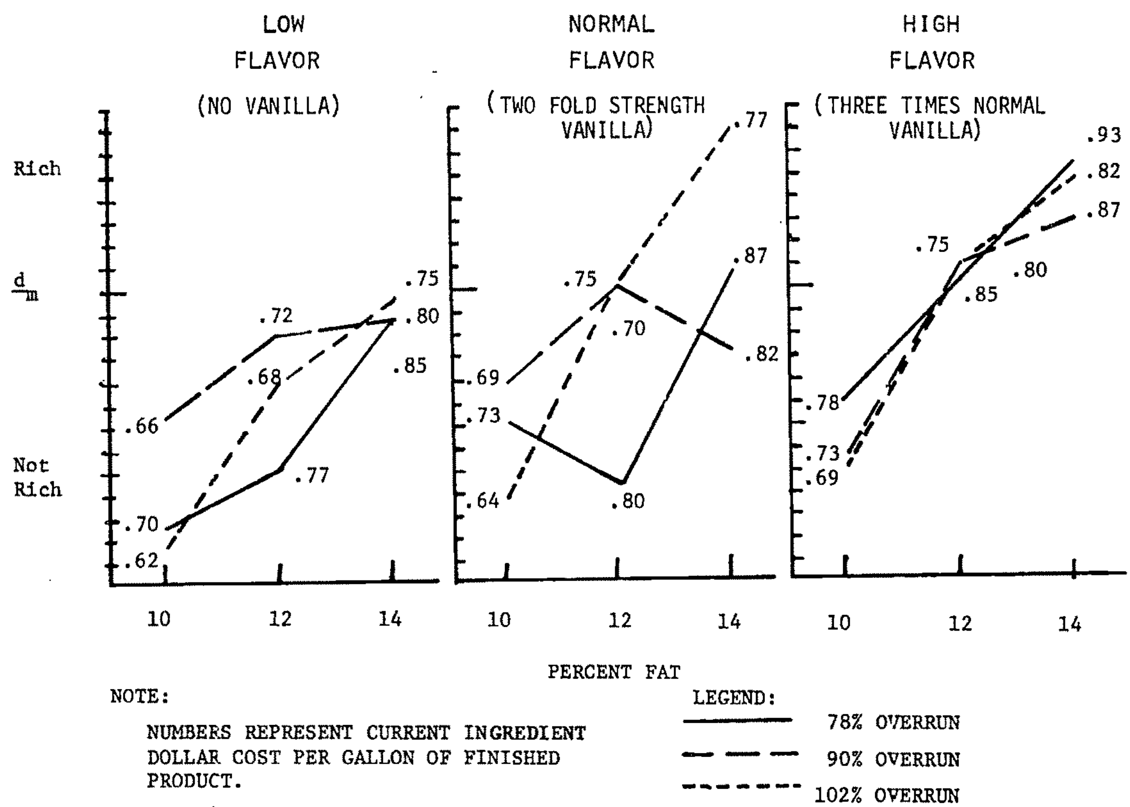


Figure 3. Relative richness ($\underline{d}_m$ value) and cost of mix

finished product. The research group had hypothesized that the richest mix would be 14 percent fat, 78 percent overrun, and triple flavor at 93 cents [3]. Note that the panel perceived 14 percent fat, 102 percent overrun, and double flavor mix as richest. The cost of ingredients for this mix was 77 cents. Note that in some instances a few cents difference in cost can produce substantial increases in perceived richness of the product, for example, *MMM* at 75 cents versus *HHM* at 77 cents. On the other hand, increasing the cost of the mix rather substantially in some cases may produce no change, or even a decrement, in perceived richness. The use of TSD methodology in this experiment has insured that these results are not restricted to the particular judgment criteria of the panel, but would be expected to hold for other panels having more stringent or less stringent criteria for judging product richness.

While the results were somewhat surprising, the conclusion is not at all unique. Over 60 years ago a group of experimenters studied ice cream mixes with methods and analyses common for that period [5]. The following is a quote from the University of Vermont Agricultural Experiment Station Bulletin 155 dated 1910:

> It may seem strange to some that an experiment station should approve the incorporation of air into ice cream. They may reason that the station advocates the dilution of the product, the selling of 'wind' as ice cream, a course quite as open to objection from the ethical, if not the legal standpoint as is the dilution of milk with water. It is a fact that an ice cream the volume of which is approximately a third air is more satisfactory to the consumer than one containing no air. It has a more velvety feel to the tongue, and conveys a sensation of richness without causing the unpleasant effects of an excessively rich cream. [5, pp. 32–33]

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# A Benefit-Burden Analysis of Public School Financing: The Impact on Rural and Urban Taxpayers*

Richard N. Boisvert and Harry P. Mapp, Jr.

**Expenditure benefit-burden ratios were developed to analyze the implications for rural and urban taxpayers of several education finance alternatives. Equalizing expenditures through a statewide property tax would transfer net benefits to high income, suburban areas. Low income rural taxpayers would benefit from greater reliance on the state income tax.**

***Key words:*** **financing education; benefit-burden analysis; taxation.**

During recent years the heavy reliance on local property tax revenues to finance public education has met with increased opposition. Taxpayer opposition centers around the belief that the property tax is regressive. Other critics, supported by a California Supreme Court decision in *Serrano v. Priest* [12], assert that the existing disparities in spending per pupil lead to unequal educational opportunity. In response to critics, states are likely to take greater responsibility for funding public education. For example, the state funding alternatives proposed by the New York State Commission on the Quality, Cost and Financing of Elementary and Secondary Education [13], better known as the Fleischmann Commission, represent a dramatic departure from existing financial arrangements. They have important implications for taxpayers, units of local government, and the quality of education.

The purpose of this paper is to demonstrate how the principles of benefit-cost analysis can be used to evaluate school financing alternatives. Emphasis is placed on estimating the proportions of educational benefits and costs accruing to families in various income categories. In particular, the procedure enables one to evaluate school financing alternatives in light of both the "benefit" and "ability-to-pay" principles of public finance. The empirical application involves an evaluation of specific financing recommendations in New York State and highlights the differential impact in rural and urban areas. The analytical framework could be used to evaluate any financing alternative.

## The Fleischmann Commission Recommendations

In 1969 the Fleischmann Commission was created to study and make recommendations on the quality, cost, and financing of public education in New York State. Its basic conclusion was that the state should be responsible for full funding of public education [13]. To help increase educational opportunity across the state, the Commission proposed that expenditures per pupil in all districts be brought up to the level of the district spending at the 65th percentile in a ranking of districts, from low to high, according to their 1970–71 base expenditures. To help alleviate spending disparities, school districts currently spending above the 65th percentile would be frozen at current spending levels until other districts were leveled-up.

The Commission was aware that many students have serious learning difficulties. Since overcoming these difficulties often requires special programs, the Commission recommended that additional funds be provided to finance specialized educational services. Each student scoring in the lowest quarter on the state's third grade Pupil Evaluation Program tests would be classified as disadvantaged and weighted at 1.5 rather than 1.0 in a district's basic expenditure allocations.[1]

In addition to their expenditure recommendations, the Commission proposed changes in school taxation as a partial solution to the inequities said to be inherent in the local property tax. A statewide property tax levied at a uniform rate of $20.40 per $1,000 of full value would initially replace existing local property tax revenues.

* Helpful comments were received from E. A. Lutz, J. J. Jacobs, and two *Journal* reviewers. Any errors remain the authors' responsibility.

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[1] The Commission designed the weighting procedure to regulate the flow of funds according to educational need. However, they recommend additional research to develop a more reliable system of identifying students with learning difficulties and to determine spending priorities.

Then, reliance on the statewide property tax would be eliminated over a five year period, with replacement revenues being derived from the progressive State income tax.

## Establishing Tax Burdens and Expenditure Benefits

The impact of the Fleischmann Commission's proposals to level-up school expenditures and alter tax liabilities is summarized in Tables 1 and 2. School spending would rise by 15.4 percent above 1970–71 levels, from $3.98 billion to $4.60 billion. Expenditures per pupil would rise from $1,182 to $1,365. The disparity in spending per pupil among county groups would fall from $260 in 1970–71 to $177, with increases being most pronounced in New York City and the extremely rural counties.

Under the 1970–71 school financing arrangements, local school districts raised $2.29 billion in property tax revenues and received $1.69 billion in state aid. Financing the increased expenditure levels by the proposed statewide property tax would increase average per family property tax liabilities from $373 in 1970–71 to $403. Property tax liabilities per family would rise in every group except group 2. However, financing with state income tax collections would shift much of the financial burden to the families in group 2 counties and lower the burden on families in the other groups.

### Tax burdens by income class

To evaluate the impact of the school financing proposals on families from different income classes, models were developed to estimate the property tax and state income tax incidence [3, 7]. Since a large proportion of school expenditures are financed from state aid, a model for estimating the combined incidence of state taxes which contribute to general fund revenues was also needed.

The property tax model has three essential components: property taxes paid by owners of residential property, those paid by renters, and those levied on commercial property.[2] The components were established separately and then combined to indicate the total property tax burden by income class.[3] Average tax burdens,

[2] The model was applied to both the 1971 and the proposed statewide property tax systems.

[3] Housing census data [17] on numbers and values of owned and rented housing units and state taxation data [10] regarding 1971 tax rates and the full value of residential and commercial property formed the basis on which the incidence estimates were made. All property taxes on rental and commercial property were passed forward to the tenant and consumer, respectively. These assumptions are extreme, but other studies by Netzer

Table 1. 1970–71 New York State school taxes and expenditures[a]

| County Group[b] | Base School Expenditures[c] | Direct Local Contribution 1970–71 Local Property Tax | State General Fund Contribution |
|---|---|---|---|
| | Thousands | | |
| 1 | $1,272,730 | $ 921,345 | $ 730,000 |
| 2 | 1,753,175 | 1,011,225 | 570,000 |
| 3 | 364,843 | 138,414 | 166,000 |
| 4 | 494,146 | 181,675 | 184,000 |
| 5 | 96,309 | 37,653 | 40,000 |
| State | 3,981,205 | 2,290,314 | 1,690,000 |
| | Per pupil | Per family | |
| 1 | $1,167 | $318 | $252 |
| 2 | 1,290 | 516 | 291 |
| 3 | 1,045 | 269 | 323 |
| 4 | 1,041 | 292 | 296 |
| 5 | 1,030 | 281 | 298 |
| State | 1,182 | 373 | 276 |

[a] School spending figures were derived from data provided by the Fleischmann Commission [13]. The methods used to establish tax liabilities, described in [3, 7], are summarized later in this section.

[b] The county groups are defined on the basis of rural population: group 1 is New York City, 2 is counties with 0–25% rural population, 3 is counties with 26–50% rural population, 4 is counties with 51–75% rural population, and 5 is counties with 76–100% rural population.

[c] Base expenditures include total general fund expenditures minus expenditures for debt service, transportation, school lunch, tuition, vocational education, and urban aid.

Table 2. School taxes and expenditures recommended by the Fleischmann Commission[a]

| County Group[b] | | School Expenditure After Leveling-up and PEP Weighting | Direct Local Contribution[c] Under Statewide Property Tax | Direct Local Contribution[c] Under State Income Tax | State Contribution General Fund |
|---|---|---|---|---|---|
| | | Thousands | | | |
| 1 | | $1,543,119 | $1,153,313 | $1,062,957 | $ 919,000 |
| 2 | | 1,915,283 | 928,676 | 1,084,588 | 717,000 |
| 3 | | 433,100 | 151,780 | 134,672 | 209,000 |
| 4 | | 587,819 | 193,187 | 157,071 | 231,000 |
| 5 | | 116,471 | 42,661 | 30,330 | 50,000 |
| | State | 4,595,872 | 2,469,618 | 2,469,618 | 2,126,000 |
| | | - Per pupil - | Per family | | |
| 1 | | $1,415 | $398 | $367 | $317 |
| 2 | | 1,409 | 474 | 554 | 366 |
| 3 | | 1,240 | 295 | 262 | 406 |
| 4 | | 1,238 | 311 | 253 | 372 |
| 5 | | 1,246 | 318 | 226 | 373 |
| | State | 1,365 | 403 | 403 | 347 |

[a] See footnote a, Table 1.
[b] See footnote b, Table 1.
[c] An area's direct local contribution is defined as the total amount of tax revenue collected from the area's residents for the expressed purpose of financing public education. Although the Fleischmann Commission recommends that the state collect and distribute the statewide property tax, its receipts are earmarked specifically for education and can be considered a direct local contribution.

obtained by dividing the total tax burden by the number of families in each income class, are presented in Table 3.

The income tax model estimates taxes paid by households in three income classes for each county by multiplying average tax liabilities for each income class by the number of returns in each income class. The ratio of county to state per capita income [11] was used to adjust the 1971 state average tax liabilities by income class to a county basis. Tax revenues needed to replace the statewide property tax would require a 115 percent increase in all income tax rates. Since the number of state returns by income class [11] was available only for the state, the distribution of returns by county was assumed to be proportional to the numbers of 1971 Federal income tax returns. Estimates of 1971 Federal income tax returns were based on the number of tax returns within zip code areas for 1966 [19]. Changes in the number of tax returns from 1966 to 1971 were assumed proportional to the changes in population [18].

All public school revenues not derived from taxes raised for the direct support of public

[9], Sears [14], and the Fleischmann Commission [13] have concluded that renters do share a great deal of the tax burden. Aaron [1] points out, on the other hand, that some business firms and industries are able to pass on a greater share of their property tax burdens than are others. Large, concentrated industries are probably better able to pass on their tax burdens. To the extent that commercial and rental property is owned by persons in higher income categories, these extreme assumptions may indicate that property taxes are slightly more regressive than they actually are.

Table 3. Average family property and income tax liabilities, in dollars, by income class and county group

| County Group[a] | Income Class[b] Less than $3,000 | Income Class[b] $3,000 to $10,000 | Income Class[b] More than $10,000 |
|---|---|---|---|
| | Property Tax, 1971 Rates | | |
| 1 | 157 | 264 | 618 |
| 2 | 245 | 381 | 901 |
| 3 | 118 | 178 | 431 |
| 4 | 139 | 219 | 517 |
| 5 | 157 | 196 | 538 |
| | Property Tax, Uniform Rate | | |
| 1 | 197 | 331 | 774 |
| 2 | 235 | 354 | 824 |
| 3 | 129 | 196 | 473 |
| 4 | 150 | 226 | 548 |
| 5 | 181 | 222 | 555 |
| | State Income Tax, at Rates Necessary to Raise Revenue Equal to Property Tax | | |
| 1 | 16 | 119 | 921 |
| 2 | 17 | 127 | 866 |
| 3 | 13 | 87 | 605 |
| 4 | 11 | 80 | 662 |
| 5 | 12 | 78 | 550 |

[a] See footnote b, Table 1.
[b] Income refers to gross income for Federal tax purposes.

education were assumed to come from the state's general fund in the form of state aid.[4] Under this assumption, the tax liabilities for the state aid portion of school revenues are proportional to state taxes paid by households in each income category. The basis for estimates of state tax burdens by income class is Lile and Soule [6], who estimated 1968 state and local tax burdens by income class for each of the 50 states. Their estimates were based on personal income, sales, property, excise, and general business taxes. Since 1971 local property tax liabilities are estimated separately, it was possible to estimate 1971 state taxes paid for each income class by subtracting present local property taxes paid from New York State's state and local tax figures reported by Lile and Soule. Families with incomes of less than $3,000 paid an estimated 8.0 percent of their income in state taxes. This figure fell to 3.9 percent for the $3,000 to $10,000 income group and to 3.4 percent for the $10,000 and above income group. These percentages, multiplied by total income by income class, provided estimates of general fund contributions by income class. Low income families shared only 1.7 percent of this tax burden, middle income families contributed 41.9 percent, and high income families across the state shared the remaining 56.4 percent.[5]

## Estimating educational expenditure benefits by income class

There are important conceptual problems involved in estimating and distributing benefits received from education expenditures. First, educational output is not easily identifiable. Second, the educational benefits accruing to any particular family depend on the number of children, the childrens' abilities and motivations, and the intrinsic value placed on education. Efforts such as those by Holland [5] and Hansen [4] have estimated private benefits from education in terms of the increased lifetime earnings resulting from additional years of schooling. Barlow [2] suggests an alternative procedure in his study of the efficiency of local school financing. A local school system is assumed to produce educational output, and benefits from public education are established by first estimating the demand for educational services. Output is regarded as proportional to educational quality, or to expenditures per pupil, as Barlow argues, if costs are constant.

In addition to including the consumption of educational services by its own children, a family's utility function, when there are externalities in consumption, may exhibit a positive marginal rate of substitution between goods it consumes directly and other families' consumption of education. Following Stubblebine [15], each demand curve is the sum of a particular family's marginal rates of substitution for education and embodies within it the family's preferences for other children's education.[6] Assuming that the $i$th family's demand ($X_i$) for education output depends on income ($Y_i$) and the price of the service ($P_i$), and that the elasticities of demand with respect to price and income are constant, the demand curve may be formulated as[7]

$$X_i = kY_i^{\alpha} P_i^{\beta}. \tag{1}$$

A family's marginal benefit equals the price it would be willing to pay for a certain quantity of education. Solving (1) for $P_i$, the following is obtained:

$$P_i = (X_i/kY_i^{\alpha})^{1/\beta}. \tag{2}$$

[4] This procedure assumes that the tax incidence of Federal aid to education, accounting for only 5 percent of school revenues, is similar to that of the combined state taxes. Because of the small amount of funds involved, the assumption is unlikely to have a significant impact on the results of the analysis.

[5] Based on these share estimates, each low, middle, and high income family contributed an average of $24, $208 and $594, respectively, to the $1.69 billion in state aid to education in 1970–71.

[6] The analysis holds for any number of families provided the assumption is made that there are no extra-local externalities or that they cancel each other. For purposes of this study this latter assumption seems justified. That is, all but five counties in New York State experienced increases in population over the last 10 years, and one might reasonably expect that any loss of educational benefits resulting from an export of human capital was offset by corresponding equal or larger gains through the import of human capital from other areas of the country.

[7] Studies, including those by Miner [8] and Holland [5], indicate that income is an important factor in determining school expenditures. Children from high income families generally have higher school participation rates and appear to make better use of their educational opportunities. High income families also are thought to derive greater intrinsic value from education and demand more education at a given price. Although the number of children affects the demand for education, state data on the number of children by income class were not available. USDA [16] estimates of average family size, ranging from 3.25 for low income families to 3.5 for middle and high income families for the Northeast region, were used to justify the assumption that family size was constant across income classes.

Similarly, Barlow [2] has shown that the total benefits at the margin to the $n$ families in society are $\sum_{i=1}^{n} P_i$. Thus, it follows that the $i$th household's percentage share of the total equals

$$(3) \qquad \frac{P_i}{\sum_{i=1}^{n} P_i} = \frac{(X_i/kY_i^{\alpha})^{1/\beta}}{\sum_{i=1}^{n} (X_i/kY_i^{\alpha})^{1/\beta}}.$$

Since each family in a given locality is exposed to the same educational system, benefit shares in the same locality are measured at the same level of educational output. Therefore, $X_i$ drops out of (3), and by simplifying one obtains (4) which is independent of the level of output

$$(4) \qquad \frac{P_i}{\sum_{i=1}^{n} P_i} = \frac{Y_i^{-\alpha/\beta}}{\sum_{i=1}^{n} Y_i^{-\alpha/\beta}}.$$

Least square estimates of the parameters of equation (1) were obtained using 1970 county data [10] for New York State. Per pupil expenditures and per capita income served as measures of education output ($X$) and income ($Y$), respectively.[8] The percent of taxable property classified as non-commercial was used as a proxy for the price of educational services (P).[9]

Equation (4) was used to estimate the share of the education benefits accruing to low, middle, and high income groups in each county of New York State. The share of educational benefits received by the families as a group was obtained directly from equation (4) by multiplying $(Y_i)^{-\alpha/\beta}$ by the number of families in each income class. These share estimates are influenced by the average income and the number of households in each income class. Summary results for the five county groups are presented in Table 4.

## Comparisons of Benefits and Costs

To evaluate and compare the Fleischmann Commission's proposals with the existing financing arrangements, the estimates of educational expenditure benefit shares and total tax costs developed in the previous sections are combined to form expenditure benefit-burden ($EB/B$) ratios. The results are summarized in Table 4.

### 1970–71 expenditures and existing local property tax

Expenditure benefit-burden ratios for 1970–71 base expenditure levels under the current system of local property taxes vary widely among income classes. In the low income category, expenditure benefit-burden ratios are less than unity in all county groups. That is, the proportion of educational costs borne by the low income group in all county groups exceeds the proportion of expenditure benefits accruing to that group under the existing local property tax system.

Expenditure benefit-burden ratios are also less than unity in county groups 1 and 2 for the

[8] As in the case of most public services, an accurate measure of educational output is difficult to find. Expenditures per pupil provided the only operational measure of output. Two difficulties arise in using expenditures as a measure of educational output. First, the cost of providing educational services differs across the state. Adjustments in expenditures per pupil are necessary in order to reflect equivalent levels of output and to provide a common basis of comparison. Second, because the effectiveness with which funds are utilized varies by school district, an exact correspondence between expenditures per pupil and educational achievement is highly unlikely. Data to test the exact nature of the relationship do not exist. To mitigate these difficulties partially, adjustments were made to reflect variations in the cost of services. Since teachers' salaries comprise a substantial portion of the base expenditure of all school districts, expenditures in Table 1 were adjusted to reflect differences in cost by standardizing expenditures according to the weighted average salary for group 5 counties. Thus, expenditures for groups 1, 2, 3, and 4 were deflated by cost adjustment factors of 1.07, 1.12, 1.01, and 1.02, respectively.

[9] Both property tax rates or tax burdens per family seem to be logical proxies for the price of education. However, because school districts constantly find it difficult to balance their budget, there is a strong *direct* relationship between tax rates and similar variables and expenditures per pupil. Such variables reflect not what people are willing to pay (or think they pay), but what they actually do pay. For this reason, regression results based on these and similar measures of price were unsatisfactory. To obtain an accurate measure of price, a variable is needed which reflects a resident's perceived cost of an expenditure increase. As argued by Barlow [2] and others, many residents may in fact view themselves as bearing little or none of the business property tax burden. That is, the larger the value of non-commercial property, the greater the tax increase on residential property, and the greater the perceived price of financing a given expenditure increase. This assumption, while facilitating the analysis, is probably quite reasonable in the case of industrial property, but is less reasonable in the case of retail and other commercial establishments whose owners reside locally and pay both business and residential taxes. Based on these assumptions, the estimated demand equation is $X = 4.40Y^{.39}P^{-.27}$. The coefficient of determination ($R^2$) is .52, and the standard errors of $\alpha$ and $\beta$ are 0.060 and 0.057, respectively.

**Table 4. Expenditure benefit shares and benefit-burden ratios**

| | County Group[a] | Income Class: Less than $3,000 | $3,000 to $10,000 | More than $10,000 |
|---|---|---|---|---|
| Benefit Shares | | Percent | | |
| | 1 | 1.51 | 45.83 | 52.66 |
| | 2 | .93 | 33.98 | 65.15 |
| | 3 | 1.03 | 41.00 | 57.98 |
| | 4 | .99 | 38.79 | 60.22 |
| | 5 | 1.03 | 40.21 | 58.77 |
| Benefit-Burden Ratios | | Ratio | | |
| 1970-71 Expenditures and Local Property Tax Alternative | 1 | 0.15 | 0.71 | 0.81 |
| | 2 | 0.17 | 0.84 | 1.18 |
| | 3 | 0.29 | 1.23 | 1.23 |
| | 4 | 0.31 | 1.31 | 1.43 |
| | 5 | 0.27 | 1.32 | 1.26 |
| Leveled-up Plus PEP Expenditures and the Statewide Property Tax Alternative | 1 | 0.15 | 0.69 | 0.79 |
| | 2 | 0.38 | 0.88 | 1.23 |
| | 3 | 0.30 | 1.24 | 1.22 |
| | 4 | 0.33 | 1.36 | 1.43 |
| | 5 | 0.40 | 1.91 | 1.82 |
| Leveled-up Plus PEP Expenditures and the State Income Tax Alternative | 1 | 0.82 | 0.96 | 0.60 |
| | 2 | 2.10 | 1.25 | 0.85 |
| | 3 | 1.17 | 1.53 | 1.11 |
| | 4 | 1.41 | 1.81 | 1.33 |
| | 5 | 2.02 | 2.57 | 1.85 |

[a] See footnote b, Table 1.

middle income class, but are greater than unity in county groups with rural populations greater than 25 percent. In the upper income class, the expenditure benefit-burden ratio is smaller than the corresponding ratio for the middle income class in only one of the county groups and is less than unity (.81) only in New York City.

### Leveled-up plus PEP expenditures and the statewide property tax

As indicated in Table 4, financing the proposed expenditure increases by a shift to a statewide property tax has little effect on the expenditure benefit-burden ratio relationships across income classes. Although the statewide tax would equalize the tax rate across the state, low income households would continue to pay 2.4 times as much in property taxes relative to their incomes as high income households.

The impact on county groups is more dramatic. Financing increased education expenditures through a statewide property tax of $20.40 per thousand dollars of full value would reduce slightly the benefit-burden ratios for the middle and high income classes in New York City. The ratio for low income families would not change. The opposite is true for the urban counties in group 2. Expenditure benefit-cost ratios are increased under the leveling-up and statewide property tax proposal. Property tax rates in this group of counties are currently above $20.40 per thousand and would fall under the statewide property tax system. The counties in groups 3, 4, and 5 are clearly helped by the increased expenditures and the shift to the proposed statewide property tax. *EB/B* ratios increase slightly for most income classes in county groups 3 and 4. As a result of substantial tax rate reductions, all income classes in the extremely rural counties, group 5, experience substantial increases in their benefit-burden ratios.

### Leveled-up plus PEP expenditures and the state income tax

When compared to the statewide property tax, financing the proposed expenditures through the progressive state income tax alters substantially the relationships among proportionate shares of expenditure benefits and costs across income classes. The primary beneficiaries of such a change would be the low income classes in every county group in New York State. As seen

in Table 4, expenditure benefit-burden ratios rise above unity in all county groups except group 1 (New York City) and range as high as 2.10 in group 2. The *EB/B* ratio for the low income class in New York City increases five-fold, even though it remains less than unity. Shifting to a state income tax would also raise the benefit-burden ratios for families in the middle income class in most areas of the state. The most significant increases occur in groups 4 and 5, respectively. Although middle income class families in New York City experience a substantial increase in their *EB/B* ratio, it still remains below unity (0.96).

Expenditure benefit-burden ratios for the upper income class reveal the most important result of the shift to a state income tax. *EB/B* ratios in county groups 1 through 4 decline, and in group 5, (low income, rural counties), increase only from 1.82 to 1.85. Thus, when compared to the proposed statewide property tax, shifting to a progressive state income tax would transfer net benefits from the high income to the low and middle income classes.

## Summary and Policy Implications

This study illustrates how benefit-cost analysis might be used to evaluate alternative methods of financing public education. Particular emphasis was placed on estimating expenditure benefit-burden ratios based on the Fleischmann Commission's school financing recommendations for New York State. This analysis relies heavily on the simplified demand function developed by Barlow [2]. Much work remains to be done to overcome the conceptual problems related to measuring educational output and price. Despite these limitations, the results of this study suggest several important policy implications for public school finance in New York State.

Under the present methods of financing public education, which rely heavily on local property taxes, the share of total education costs borne by low income families exceeds their corresponding share of the expenditure benefits. A more equitable system would insure that low income people receive a greater proportion of the benefits, support a smaller share of the tax burden, or both.

Financing more equal but increased expenditure levels by a uniform rate statewide property tax transfers net benefits, largely in the form of increased tax burdens, from New York City, counties with a central city, and some rural counties, to the high income, suburban areas. Although expenditure benefit-burden ratios increase for low income families in all county groups except New York City, they remain far below unity. Thus, it appears that equalizing expenditures and property tax rates across the state is not likely to result in an educational finance system which is equitable to low income families.

Financing increased expenditures by a state income tax would, however, alter substantially the relationships between expenditure benefits and burden shares across income classes. The primary beneficiaries would be the low income families throughout the state. In the low and middle income classes, expenditure benefit-burden ratios would be greater than unity in all county groups except New York City. Furthermore, much of the tax burden would be shifted from low income, rural counties to high income, urban counties. One might conclude from this evidence that dramatic revisions in the current system of school taxation are likely to be more effective in equalizing costs and expenditure benefits for all income classes than are adjustments in school expenditures.

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# Benefits and Costs of a Physician to a Community*

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**The Pacific Northwest as one planning region does not appear to have a shortage of physicians. However, a serious misallocation of physicians within the region prevails. Construction of hospitals by rural areas as a means of attracting additional physicians may not always be a wise investment.**

***Key words:*** **benefit-cost analysis; physician; health status; rural health.**

STEEPLY RISING medical costs and the inaccessibility of health care to residents in the rural areas are causes of growing concern in this country. The Comprehensive Health Planning Act of 1966 and the Partnership for Health Amendments of 1967 reflect this public concern about the present allocation of health care resources. These acts establish a mechanism for comprehensive areawide and statewide planning that can identify health problems and establish priorities in the allocation of resources.

Both a general understanding and specific estimates of the basic behavior relations of the health care system are a prerequisite for appropriate policy decisions. Information is needed about the process of producing health in this region if Comprehensive Health Planning in the Pacific Northwest is to promote efficient utilization of resources. The objective of this study was to create a model which could be used to examine empirically the economic impact of public and private decisions affecting the health status of the population. Information from this model can be used to ascertain the economic efficiency of proposals that would affect the availability of medical care or change the general health status in the Pacific Northwest.

Historically, raw or age adjusted mortality statistics have been used to measure the health status of a community. Recent examples are studies by Adelman [1], Auster [4], and Larmore [13]. These studies, however, do not quantify the economic loss due to early deaths. The loss of a life indicates an actual loss to society of a productive and consuming unit. Such a loss discounted to the present can measure the costs of early deaths to society.

This study applies one measure for evaluating the health status of the population and for assessing the impact on the health status of environmental, social, economic, and other related factors. Using the concept of human capital formation, it is hoped that an objective evaluation of the economic benefits of better health, compared with the costs of securing it, will be of aid to local and regional governmental units in making rational expenditure decisions.

It was decided to analyze the productivity of health care inputs by Comprehensive Health Districts because regional districts carry out planning by the states. The Pacific Northwest region of the United States (Oregon, Washington, and Idaho) was chosen for the area of study because of a belief that to contribute in any meaningful way at the state and regional levels, disaggregated empirical studies have to be conducted. Studies utilizing a higher level of aggregation have shown the importance of a disaggregated approach to health care policy [12]. The unit of observation in this study is the county, mainly because of the availability of data.

## Econometric Model

In regressing the health status of a county on the medical, social, economic, and geographic characteristics of the counties, it is hypothesized that several explanatory variables are correlated with the disturbance term, i.e., that there is some interdependence between a community's health status, the availability of physicians, and the income of that community. Health status is determined not only by the availability of physicians but also by the economic position of the individual. The availability of a physician's services is a function of the health status of an individual and the ability to pay for services received. Also, an individual's income can be dependent on his health status in two ways: an

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ill person may become lethargic and not have the drive to advance on his job, or a person may be ill and not working, receiving no reportable income. To deal with the problem of simultaneity, the two-stage least squares method was used.

The following equations represent the model that was employed:

**Production of health**

$$(1)\quad X_{18} = \beta_{1,0} + \beta_{1,1}X_1 + \beta_{1,2}X_2 + \beta_{1,3}X_3 + \beta_{1,4}X_4 + \beta_{1,5}X_5 + \beta_{1,6}X_6 + \beta_{1,8}X_8 + \beta_{1,9}X_9 + \beta_{1,10}X_{10} + \beta_{1,11}X_{11} + \beta_{1,12}X_{12} + \beta_{1,14}X_{14} + \beta_{1,15}X_{15} + \beta_{1,16}X_{16} + \beta_{1,17}X_{17} + \mu_1$$

**Physician availability function**

$$(2)\quad X_{16} = \beta_{2,0} + \beta_{2,1}X_1 + \beta_{2,2}X_2 + \beta_{2,5}X_5 - \beta_{2,7}X_7 + \beta_{2,9}X_9 + \beta_{2,10}X_{10} + \beta_{2,11}X_{11} + \beta_{2,12}X_{12} + \beta_{2,14}X_{14} + \beta_{2,15}X_{15} + \beta_{2,17}X_{17} + \beta_{2,18}X_{18} + \mu_2$$

**Income generating function**

$$(3)\quad X_{12} = \beta_{3,0} + \beta_{3,1}X_1 + \beta_{3,2}X_2 + \beta_{3,3}X_3 - \beta_{3,4}X_4 + \beta_{3,5}X_5 + \beta_{3,6}X_6 - \beta_{3,7}X_7 + \beta_{3,8}X_8 + \beta_{3,9}X_9 - \beta_{3,10}X_{10} + \beta_{3,11}X_{11} + \beta_{3,13}X_{13} - \beta_{3,18}X_{18} + \mu_3$$

where

| | | means of variables |
|---|---|---|
| $X_1$ | = index of population concentration | .65697 |
| $X_2$ | = median years of education | 12.179 |
| $X_3$ | = percent of population non-white | .02405 |
| $X_4$ | = percent of population under age 18 | .35370 |
| $X_5$ | = percent of population over age 62 | .13413 |
| $X_6$ | = percent of population in manufacturing | .18180 |
| $X_7$ | = percent of population professional workers | .13077 |
| $X_8$ | = percent of population farmers & farm workers | .20432 |
| $X_9$ | = percent of population migrated in the last five years | .25339 |
| $X_{10}$ | = percent of families with income less than $3,000 | .10589 |
| $X_{11}$ | = percent of families with income over $15,000 | .13775 |
| $X_{12}$ | = median income per family in dollars per year | 8574.1 |
| $X_{13}$ | = per capita tax assets in dollars | 13336 |
| $X_{14}$ | = number of inhabitants per hospital bed | 362.29 |
| $X_{15}$ | = number of inhabitants per paramedic | 254.14 |
| $X_{16}$ | = number of inhabitants per physician | 1646.3 |
| $X_{17}$ | = per capita Health Department budget in dollars per year | 3.9705 |
| $X_{18}$ | = health status as measured by mortality losses | .99658 |

The variables in the income determination equation are included because they are relevant to the theory of health production and the availability of physicians. The equation has deficiencies if viewed as a theoretical statement of income determination. It is agreed that if the specification of the income determination were more accurate, then the estimated coefficients would also be more accurate. However, bias is reduced in the estimation of the production of health and the availability of physicians by explicitly having income depend on the exogenous variables that appear in the other two equations.

## Hypothesized Relationships

Several geographic, demographic, medical, and economic variables and their relationships to the health status of a county and availability of physicians are discussed below. These hypotheses are based on reported empirical analysis and on descriptive material available. (The variables in the income equation are not discussed because of the incompleteness of the equation.)

### Health status

Difficulties have been encountered in developing models to measure the adequacy of community services. Most appraisals of the adequacy of medical care have been in terms of number of physician visits, number of patient days in hospitals, qualification of physical plants, and the use of "medical audit" [2]. While such measures may reflect qualitative standards, they are unacceptable in measuring the output of health care because they do not appraise the end result —the health status of a community.

The health status of a county in the Pacific Northwest, as defined in this study, reflects

economic loss due to mortality in 1970.[1] Some economists [22] and insurance companies measure the mortality effects of disease by determining the present value of the production which the deceased would have contributed less what he would have consumed. Others [8, 18] concede that it may be true that a man consumes partly in order to maintain himself, and in this sense some of his consumption may be considered as a gross investment to take care of depreciation. It is also true that consumption is an end in itself and can be viewed as a final, rather than an intermediate, step in the creation of other products.

This study uses aggregate mortality statistics combined with Dorothy Rice's method [18, p. 93], which measures the gross economic value of a person to society, to estimate the health status of a county.[2] This health status is represented by a health index:

$$X_{18} = \frac{\sum_{i=1}^{2} \sum_{j=1}^{19} M_{ij} Z_{ij}}{\sum_{i=1}^{2} \sum_{j=1}^{19} N_{ij} Z_{ij}} \tag{4}$$

where

$X_{18}$ = health index of a county,
$i$ = sex,
$j$ = age group,
$M$ = number of sex-age specific deaths,
$Z$ = present value of sex-age group,
and
$N$ = number of inhabitants in sex-age group.

The total human capital inventory of a county (denominator) is used to create a health index ratio designed to provide a method of comparing the health status of counties. The numerator alone would appear as a dollar figure, dominated by population size, and would be misleading in absolute numbers. Use of the total human capital inventory as the divisor creates a positive health index; a higher index reflects fewer economic losses.

[1] The health status of a community in one time period may be a function of the preventive medical and health care provided in past time periods. The inclusion of this recursive relationship would create many other statistical problems. The assumption is made that such preventive medical and health care in a community is constant over time.

[2] Accidental or homicidal deaths not included. The causes of such deaths may be dependent on factors unrelated to "natural deaths."

**Variables included in equation (1), health status**

$X_1$ = index of population concentration. An "index of concentration" measures the amount of concentration of the population around the health facilities of a county [17, p. 49].

For the United States as a whole, Auster [4, p. 42] and Larmore [13, p. 27] conclude that urbanization and population may either not affect mortality or may have a significant positive relationship with mortality. It is hypothesized that in the Pacific Northwest, the difference in environmental sanitation and housing between urban and rural areas is negligible, but that there is a negative relationship between the health status of counties and urbanization due to the stress of life and the degradation of the physical environment.

$X_2$ = median education level of the population over 25 years. Education is probably more important in increasing the healthiness of a population than any other factor. Formal education tends to increase the search for and the acceptance of information relating to one's well-being.

$X_3$ = percent of the population which is non-white. It is often stated that at any given level of education, income, etc., non-whites tend to be less healthy than whites. Blacks, for example, have a shorter life expectancy, a high infant mortality rate, and a higher death rate from infectious diseases than whites [21, p. 2].

$X_4$ and $X_5$ = percent of the population under 18 and percent of the population in a county over 62. In a sense the health index discussed above adjusts the model for age-specific deaths. Nevertheless, mortality and old age are inseparable, and one expects a county with a greater number of old people to have a lower health status than counties with younger populations.

$X_6$, $X_7$, $X_8$, and $X_9$ = percent of population in manufacturing; percent professional workers; percent farmers or farm workers; and percent of the population having migrated in the last five years. It is hypothesized that there may be special positive attributes in living and working in a rural area. This does not in any way suggest that the special groups within agriculture, for example the seasonal migrant farm workers, may not have serious health problems. (The 1970 U. S. Census, taken in April, would have missed this large portion of agricultural labor since most of the migrants from the Southwest would not yet have started their move into the Northwest.)

Workers employed in manufacturing (forest-related industries) in the Northwest may share with agricultural workers many of the positive attributes of rural life, but in addition they have greater access to medical care facilities because of insurance plans which larger manufacturing firms offer.

It is hypothesized that it is the more aware citizens who tend to migrate. This awareness may manifest itself in greater acceptance of preventive health actions. Another possibility is that the age group most likely to move in search of better opportunities is the lower middle age group, i.e., those persons least likely to die because of health problems.

$X_{10}$, $X_{11}$, and $X_{12}$ = percent of families with income under $3,000, families with income over $15,000, and median family income. It was decided to use several measures of income to develop a clearer relationship between income and health. Referring to the interrelationship between income and the health status of a county, a negative relationship between health and the low and median income variable is postulated.

Insofar as poor people tend to have more chronic illnesses and are less aware of and less able to take part in the benefits of preventive health care, a shorter life span would be expected.

It has often been hypothesized that the middle income group does not have the benefits of governmental income redistribution programs nor do they have adequate finances to demand effectively all the health care inputs they desire. Assuming that all variables such as age, education, and urbanization are evenly distributed, it has been found that the middle income group has lower medical care expenditures than the poverty or high income groups and that the medical expenditures by the high income families were half again as high as those in the average income group [23, p. 120].

$X_{14}$, $X_{15}$, $X_{16}$, and $X_{17}$ = number of inhabitants in the county per hospital bed, number of inhabitants in the county per paramedical personnel, number of inhabitants per physician, and per capita public health expenditures. Medical care provided by physicians, paramedical personnel, and hospital beds can most usefully be separated into two main areas, namely, prevention and treatment. Prevention in this context is defined to include prenatal care, well-baby clinics, and yearly checkups. Treatment, on the other hand, includes those services needed by the chronically ill, such as ulcer treatment and heart problem treatments usually provided by a hospital. The physician's and paramedic's time is divided between treatment and prevention.

Stewart concludes that "improvement in health resulting from better treatment has little effect on increased longevity" [20, p. 121]. One would, therefore, expect the physician and paramedical personnel variable to be positively, and the hospital variable to be negatively, associated with the health index.

In conversation with public health officials, it has not been possible to isolate a specific objective of public health. It is hypothesized that the collection of statistics and the dissemination of information leads to wiser public decisions and better health.

### Availability of physicians

Use of medical care inputs depends on the availability of care and on the individual's ability to pay (demand) these inputs. Although the individual may be the entrepreneur who oversees the production of his health, the physician, because of the patient's ignorance and the institutional constraints, takes over the role of manager in much of the health production process.

Physicians remain the most important resource in the provision of medical care. Even though the physician only comprises 6 percent of all health manpower [12, p. 148], his services directly consume 23 percent of the consumer's medical care expenditure [9, p. 121]. Indirectly, his activities are also responsible for consumer expenditures on other health care professionals and on drugs.

### Variables included in equation (2), physician availability

Several studies have surveyed practicing physicians with regard to their attitudes toward the placement of their practice [5, 6, 14, 16]. These studies indicate that financial considerations, the availability of nearby medical facilities and consultive services, cultural or educational opportunities for their families, and possible scarcity of non-medical professional comradeship were some of the most important factors considered when setting up practices. The variables ($X_{12}$, $X_{14}$, $X_1$, $X_7$) are expected to be negatively related to the number of inhabitants per physician ratio. A positive relation is expected with $X_{10}$ and $X_{11}$.

Total expenditures (private plus public) of low income individuals on medical care may be higher than other groups, but this is mostly

because of their ability to secure free care under welfare and charity programs. As shown by Wirick's study [23, p. 120], the middle income group has lower medical expenditures than the poverty or high income groups. Grossman [10, p. 246] suggests that educated people ($X_2$) have an incentive to offset part of the increase in health caused by an increase in education by reducing their purchases of medical services.

The aged ($X_5$), more apt to be suffering from chronic illnesses, put a greater strain on medical care services. They average 6.8 visits to a physician per year as compared to 4.8 percent for those under 65 [11, p. 333]. Younger people are more aware of their surroundings and are most likely to migrate ($X_9$). They also demand less treatment for acute or chronic illness. In that a substantial investment is involved in setting up a medical practice, one would expect a time lag between the growth of a community and the willingness of a physician to establish an expensive practice in that community.

In many areas of severe shortages of medical doctors, physician substitutes are being introduced by government programs. It is hypothesized that the natural order of correcting for shortages (i.e., the market place) has also been at work and that there is probably some substitution taking place between physicians and paramedical personnel ($X_{15}$).

Finally, it is hypothesized that the higher fees brought about by the provision of government medical services will attract additional physicians [9, p. 128]. One of the basic requirements for a physician's visit is a physical condition, or a felt physical condition, that requires the attention of a physician. Holding everything else constant, it is hypothesized that physicians respond positively to such requirements by moving to areas with lower health status ($X_{18}$).

## Empirical Results[3]

Table 1 presents estimates for the coefficients of the determinants of health status using two-stage least squares regression, while the estimates of the coefficients that determine the availability of physicians are given in Table 2.[4,5]

**Table 1. Two-stage least squares regression of health indices—on selected exogenous and estimated endogenous variables**

| | Variable | Coefficient | Asymptotic Standard Errors |
|---|---|---|---|
| $X_0$ | Constant | 1.000 | .01674*** |
| $X_1$ | Index of population concentration | —.002 | .00107* |
| $X_2$ | Median education | .001 | .00086* |
| $X_3$ | Percent non-white | —.0001 | .00721 |
| $X_4$ | Percent under 18 years | .007 | .00748 |
| $X_5$ | Percent over 62 years | —.020 | .00949** |
| $X_6$ | Percent in manufacturing | .009 | .00284*** |
| $X_8$ | Percent farmers and farm workers | .005 | .00350* |
| $X_9$ | Percent migrated | .006 | .00365* |
| $X_{10}$ | Percent in poverty | —.023 | .01614* |
| $X_{11}$ | Percent with income over $15,000 | .010 | .01685 |
| $\hat{X}_{12}$ | Median income | —.000002 | .0000010* |
| $X_{14}$ | Inhabitants per hospital bed[a] | .000003 | .00000146** |
| $X_{15}$ | Inhabitants per paramedic[a] | —.000007 | .00000071*** |
| $\hat{X}_{16}$ | Inhabitants per physician[a] | —.000001 | .00000057** |
| $X_{17}$ | Per capita Health Department budget[b] | —.000080 | .00011587 |

[a] A positive sign designates a negative relation (or vice versa) since more hospital beds, paramedics, or physicians are represented by a lower number.

[b] The observed sign is not consistent with the hypothesized sign.

*, **, *** Significant at the 10 percent level, 5 percent level, and 1 percent level, respectively.

Several variables included in the equation are far removed from control of policy makers in public health. However, an understanding of the relationship between health status of a community and environmental and social factors

[3] An attempt was made to use morbidity rates (economic loss due to notifiable diseases) instead of mortality rates. The results led to the conclusion that the model was not specified very well. The concern with using morbidity statistics on only a few diseases is that these reports are greatly influenced by the number of Public Health staff and the vigor of their reporting activities.

[4] Using Farrar and Glauber's method [7, p. 99], the variance—Var ($\hat{\beta}_{12}$)—was estimated to be 58.20 times as high as it would be had $\hat{X}_{12}$ been completely independent of the other variables. To eliminate those variables that apparently are the cause of some multicollinearity, such as $\hat{X}_{12}$ and $X_{11}$, would damage the specification of the theoretical model. The decision was made to use the results of the previous specified model with the awareness that the precision of some of the estimated coefficients may not be as high as they would be if there were no interdependencies.

[5] The reduced form coefficients were calculated. They were not markedly different from the two-stage least squares estimates.

Table 2. Two-stage least squares regression of inhabitants per physician[a] —on selected exogenous and estimated endogenous variables

| | Variable | Coefficient | Asymptotic Standard Errors |
|---|---|---|---|
| $X_0$ | Constant | 64588 | 138536 |
| $X_1$ | Index of population concentration | −1244 | 524.88*** |
| $X_2$ | Median education | 919 | 384.81*** |
| $X_5$ | Percent over 62 years | −5300 | 4040.8* |
| $X_7$ | Percent professionals | −11272 | 2687.5*** |
| $X_9$ | Percent migrated | 2765 | 1444.8** |
| $X_{10}$ | Percent in poverty | 9933 | 6783.8* |
| $X_{11}$ | Percent with income over $15,000 | −12336 | 6001.6** |
| $\hat{X}_{12}$ | Median income | .39 | .41091 |
| $X_{14}$ | Inhabitants per hospital bed | 2.40 | .24027*** |
| $X_{15}$ | Inhabitants per paramedic | −.69 | .92917 |
| $X_{17}$ | Per capita Health Department budget | −45 | 54.094 |
| $\hat{X}_{18}$ | Health index[b] | −74478 | 136760 |

[a] The physician variable is a negative measure and the signs, except for $X_{14}$ and $X_{15}$, should be interpreted as the opposite of what they appear in the table.

[b] The observed sign is not consistent with the hypothesized sign.

*, **, *** Significant at the 10 percent level, 5 percent level, and 1 percent level, respectively.

can be a helpful planning tool. In terms of public policy, rarely has there been an effort to influence the flow of people away from areas of industrial growth; however, rapid technological growth and a very mobile population are exerting such strong pressures on the remaining natural resources in certain areas that there is growing awareness for the need to plan the dispersion of people. The negative sign of the population concentration variable $X_1$ in Table 1 would indicate that the crowding of the population into metropolitan areas may also be detrimental to the health of its populace.[6]

Education in itself has long been accepted as a worthwhile investment by a community. Most societies also have a very conscious public policy to alter income distribution. The positive signs of $X_2$ (median education) and the negative sign of $X_{10}$ (percent in poverty) suggest that the social objectives of higher education and income redistribution can also lead to a healthier society. These results do not mean that more expenditures are warranted to increase the health status of a society because the marginal costs may be greater than the marginal returns.

A negative sign of a coefficient resulting from analysis of a production function would designate a negative causal relationship between the input variable and the output. In this instance, where the sign of the hospital bed variable is negative, this does not necessarily mean that hospital beds are the cause for greater deaths among the population. A more likely explanation is that hospitals are built for a group that requires greater treatment and that has a greater possibility of dying in any one time period.[7] By only looking at the investment output of health, this group's economic loss from deaths is proportionately larger. Medical treatment in almost every other study has a low marginal productivity with respect to longevity [20, p. 56] because hospitals offer a greater proportion of services as treatment than as prevention. Community pride or a feeling of altruism, together with the Hill-Burton Act, which allows communities to bear only part of the total cost of hospitals, are other reasons for having larger hospitals than might be needed.

## Investment in Physicians

For the entire Northwest, the annual marginal value product of a physician is estimated to be $35,511;[8] at that point, where the Pacific Northwest employs doctors, if it were to employ one more, it would save the area $35,511 per year in economic loss due to productivity lost from early deaths.[9]

6 This assumes that people do not systematically move to the cities to die.

7 An anonymous reviewer suggests that, according to other evidence, hospital construction is essentially random and not correlated with anything.

8 Using the results of Table 1, the marginal value product for physicians in a specific area is:

$$(T_i)\frac{\partial X_{18i}}{\partial D_i} = \frac{.000001\,(N_i)}{D_i^2}\,(T_i)$$

where $T$ = human capital, $X_{18i}$ = health index, $D$ = number of physicians, $N$ = population, and $i$ = geographical area. The estimates of the "marginal value product" of a physician would in all likelihood have been greater if the analysis had included the direct economic loss of illness.

9 The American Association of Medical Colleges [3] has conducted a study of about 30 medical colleges to

The average annual gross earnings of a physician in the Northwest is $67,396 [15, p. 77]; it would cost the community $67,396 to attract another physician to their community (considering the money alone will be incentive). By analyzing the productivity of physicians by Comprehensive Health Districts, it was found that 23 C.H.P. Districts had M.V.P. > M.F.C. (marginal factor cost is defined to equal the price of an additional physician). These districts could justify seeking the services of an additional physician. However, for the Pacific Northwest as one planning district, the shortage of physicians disappears. Apparently there is not so much a physician shortage as there is a misallocation of the existing physicians.

One of the more important factors that physicians consider in placing their practices is the availability of hospitals [5]. If the population/physician ratio ($X_{16}$) is considered the output (physician availability function of the simultaneous equation), then the marginal product of a reduction in the inhabitants per hospital bed ratio is 2.40 (Table 2). That is, a reduction in the inhabitants per hospital bed ratio by one unit will decrease the inhabitants per physician ratio by a multiple of 2.40. The average annual cost of a hospital bed is estimated to be $36,865 [19], compared to the $67,396 annual income an additional physician would generate. For any geographical area the per inhabitant cost of a hospital and per inhabitant benefit of an additional physician would depend on the population of that area. If hospital beds were evenly distributed throughout the Northwest, the cost of decreasing the inhabitants to hospital bed ratio was found to be about equal to the benefits derived therefrom ($242 > $241).[10] For the C.H.P. Districts, however, in 17 out of 36 districts the costs would exceed the benefits derived therefrom. The rural areas especially would find the difference substantial. From these statistical relations it would seem that hospital construction would not be a wise investment for rural areas whose main objectives are to create facilities that will attract additional physicians.

## Conclusions

Planners in the past have used population/manpower ratios to suggest a shortage of medical inputs (physicians or hospital beds) in certain areas without considering the obvious fact that there are also some areas whose population/medical input ratios are far in excess of the desired ratio. The results of this study indicate that there is an excess of hospital beds in the Pacific Northwest and that instead of building new hospital facilities to treat patients and to attract physicians, it would be more efficient to increase the number of physicians directly, even if this requires paying higher salaries. A local community trying to attract a physician would be allocating its resources more efficiently by subsidizing with a minimum salary, by paying for part of his cost of training, or by building clinics for the free use of physicians.

Increasing the general supply of physicians is not likely actually to bring them to the rural areas for some time. Because of the rigid price structure in the medical profession and the demand that exists everywhere for physician's services, it is expected that an increase in the total number of physicians would only serve to attract a large part of the increment to areas with already formidable physician to population ratios. Consideration should be given not only to programs that increase supply, but also to specific proposals to place physicians in the areas that can point to a need for those services as well as the ability to support them.

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delineate costs of education and training students; the estimated four year cost averaged $20,400 per year in 1972. In 1970 dollars these costs would be very close to the average annual gross earning of a physician. It could be argued that a local community can pay for the training of a physician with a "forgiveness loan" at a cost of about $20,000; however, these programs have not been very successful since the trained physician can repay the loan and locate somewhere else.

[10] For the Pacific Northwest the population/physician ratio is 670; the per inhabitant benefit of an additional physician is therefore calculated to be $241 = (2.40)$67,396/670.

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# Compensating the "Human Costs" of Increased Productivity of Fluid Milk Drivers*

LYNN G. SLEIGHT AND JAMES W. GRUEBELE

"Productivity bargaining" provides a mechanism for sharing mutual benefits of increased productivity between management and labor. Minneapolis milk driver contract provisions limit wholesale route size, thus limiting driver productivity. Using severance pay as an example of "human cost" compensation, calculations demonstrate potential bargainable gains from increasing productivity through larger routes.

*Key words:* productivity bargaining; human cost; labor productivity; collective bargaining.

IMPROVED TECHNOLOGY has created pressures for increased driver productivity in fluid milk delivery, resulting in charges that the "human costs" incurred may not be adequately appreciated in labor negotiations. To minimize or prevent certain human costs, some milk driver unions have maintained contract provisions limiting driver productivity indirectly while others have been able to limit productivity directly through limiting the volume delivered per driver per unit of time. In the interest of greater labor efficiency concurrent with greater fairness to the workers involved, a new emphasis has emerged in the labor-management relations field: productivity bargaining.

> In productivity bargaining, management and labor write an agreement that establishes a set of *quid pro quos* whereby (a) labor agrees to scrap old work habits for new and more effective ones desired by management, and (b) management returns some of the gains of modernization and increased efficiency to labor in the form of new and better work incentives. [6, p. 78]

Change and efficiency are explicitly primary goals of productivity bargaining whereas in ordinary collective bargaining the usual goals center around continued production with minimum change. Productivity bargaining is based on mutual gains through increasing productivity, and has been described as a game in which "the gains must tempt both parties; everybody must play the game, and everybody must win" [7]. It is likely to be more successful if handled apart from the pressures and deadlines of contract renegotiations.

A basis for consideration of mutual benefits in technological change has been suggested from negotiations in the longshore industry:

> Technological change is inherent in industrial progress. A fundamental premise is that management should be free to improve equipment, to develop more efficient methods, and to maintain its operation in a manner that will keep it competitive.
>
> Also fundamental is the premise that the cost of technological change should not rest entirely on the employees of the industry. [5, pp. 140–141]

Increased productivity is usually desirable, and productivity bargaining brings consideration of the associated human costs explicitly into focus.

Sleight proposed that loss of jobs, increased workloads, and uncompensated increases in driver productivity are meaningful examples of human costs. He further suggested four methods of sharing human costs: pacing innovation adoption to worker attrition rates, severance pay, incentive pay, and industry study committees [8]. The study committees are similar to the "change agents" suggested by Rosow. Rosow has suggested that a direct improvement in wages and benefits and a clear understanding of job security are among the trade-offs usually attractive to labor. The exchange of these benefits for relaxation of restrictions on innovation in the fluid milk industry could benefit both workers and management with spinoff benefits to producers and consumers as the marketing system becomes more efficient through greater labor productivity.

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## Hypothetical Example

Figure 1a represents part of a hypothetical labor cost function where a productivity limit is in effect. Productivity is expressed as route size in units delivered by drivers per day, larger routes being more productive than smaller routes. The status quo is represented at point $A$ where route size is $s_o$ with per-unit cost of $c_o$. If a larger route size limit could be negotiated, scale effects would tend to lower the per-unit costs. However, the change would depend on the level of human cost compensation ($HCC$) required by the workers for relaxing the productivity restriction. An all-powerful union able to require a large $HCC$ for increased route size could mean no reduction in per-unit costs (Curve $AB$). An all-powerful management could force settlement at zero $HCC$ (Curve $AD$). Any rational settlement would be at or between these extremes.[1] Figure 1b represents the same function expressed in terms of monthly earnings by drivers rather than in per-unit costs.

[1] While bargaining greater productivity vs. Human Cost Compensation is analytically kept separate from regular wage bargaining in this paper, in practice the two may occur simultaneously. The vertical placement of the curves is set by the current contract provisions. New wage rates or other benefits would tend to cause vertical displacement while certain changes in type of pay, such as commission rates, may change the slopes.

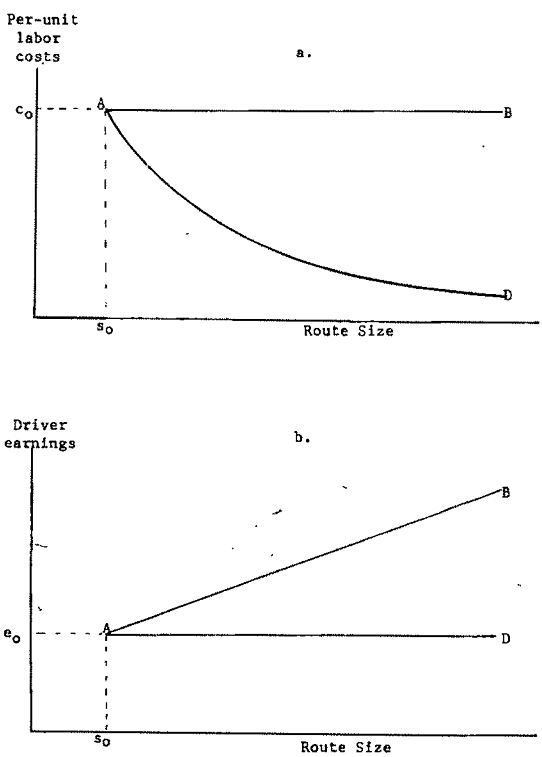


Figure 1. Hypothetical relationships among route size, when restrictions to size are relaxed, per-unit costs, and driver earnings

## Empirical Application

The above hypothetical analysis was applied to 1969–70 contractual provisions in the Minneapolis Market to demonstrate use of $HCC$ as recompense to wholesale milk drivers for relaxing their limit on productivity through productivity bargaining. The Minneapolis market was used as an example since the limit of 3,500 quart-equivalents per wholesale driver per day is a straightforward productivity limitation, the driver pay plan is a relatively simple base-plus-commission pay plan, and the limit has been publicized in other research [cf. 1]. The Duluth-Superior and Pittsburgh markets also have maximum volume limits for wholesale drivers, but other features of these contracts and pay plans make calculations of negotiated pay levels more complex and thus less satisfactory for use here as an example. The analysis is adaptable, however, to other markets and to consideration of contractual provisions other than those used here.

Severance pay[2] is used to represent a form of $HCC$, i.e., *ex ante* compensation to drivers for accepting the risk of job loss from increasing their productivity.

While it could be argued that the Minneapolis market is somehow unique with little opportunity to increase route size, there is evidence that technology permits considerably larger loads than the Minneapolis contract allows. Table 1 shows some actual route sizes in several markets, indicating that drivers without helpers in other markets handle considerably larger loads, i.e., are more productive, than drivers in Minneapolis. While small-store routes may be smaller than Minneapolis routes, they represent very few stores and only a small portion of total fluid milk volume. Supermarket and integrated store

[2] Severance pay as used here is a fringe benefit extended by management in the form of negotiated contributions to a severance fund from which workers discharged through no fault of their own (normally due to innovations or new technology) would draw compensation to help them make the transition to new employment. It is only a *potential* benefit to those workers who never lose their jobs in this manner; the immediate benefit to all workers is its effect as a deterrent to the uncertainty of income should job loss occur. Severance pay is conceptually an additional compensation over and above the regular wages bargained for, although in practice it is often treated as part of a package deal.

Table 1. Wholesale route sizes in six markets, 1969–70

| Market | Route volume, no helpers | Remarks |
|---|---|---|
| | points per day | |
| Chicago | 1,667—1,867 | "Ma&Pa Store" routes |
| | 3,333—5,000 | Modal range, all stores |
| | 3,200—4,800 | "Small" routes of integrated operator (A) |
| | 8,000 | "Average" routes of (A) |
| | 11,200 | "Large" routes of (A) |
| | 12,000+ | Routes of integrated operator (B) |
| Des Moines | 3,864—4,545 | Route average, except large routes |
| | 14,000 | Route average, large routes |
| Kansas City | 6,000 | Route average |
| Minneapolis | 2,741—3,500 | Route average |
| New York | 3,027 | Stores other than supermarkets |
| | 7,929 | Supermarket routes[a] |
| St. Louis | 5,600—6,000 | Route average |

Source: Unpublished correspondence and interviews with union and processor personnel by the writers.

[a] Supermarkets handled 30.0 percent of total U. S. fluid milk volume in 1967, while grocery stores other than supermarkets and convenience stores handled 10.6 percent [4, p. 11].

operations, which handle a large proportion of total volume through stores, tend to be serviced by routes considerably larger than those in Minneapolis.

In this analysis increased productivity will be defined as an increase in route size so that each driver delivers more per day than under the status quo. "Human cost" will be defined as the probability of loss of driver jobs due to a decrease in route numbers if the productivity limit were relaxed. These are both straightforward concepts and represent major concerns of both management and labor. Severance pay will be analyzed as the payment to drivers to compensate them for human cost (i.e., probability of job loss if productivity is increased). Severance pay for milk drivers was found in 13 of 76 labor contracts studied by the writers and is a bargained fringe benefit. While the form of payment of *HCC* would be important in actual negotiations, this analysis will assume that the severance benefit to a driver whose job is eliminated would be the value of management's severance pay contribution on a monthly basis.[3]

*HCC* (severance pay in this example) could be given to drivers either as additional pay or as a fringe benefit contribution.[4] In a sample of 57 contracts studied, 18 provided that higher base or commission rates would apply when certain productivity-increasing innovations were adopted. In those markets a form of *HCC* was given directly as increased pay rather than as a fringe benefit.

This analysis assumes that both management and labor are amenable to productivity bargaining in the Rosow sense, i.e., both are willing to expend time and effort in developing the set of *quid pro quos* that would increase worker productivity while at the same time allowing drivers some level of compensation for the human costs involved.

Table 2 shows calculations of the bargainable range of *HCC* for route size increases in the Minneapolis example. In this table the 3,500 point per day level (the 1969–70 contractual limit) is the point of departure for the analysis. All calculations relate to expansions in productivity from this point. The status quo per-unit costs of 1.485 cents per point and monthly earnings of $1,039.53 were, of course, negotiable values derived from the wage and fringe benefit levels of the contract that was current in 1969–

[3] In an actual case the severance benefit would likely depend on a formula of some kind tied to tenure, pay scale, interest accrued by the fund, and costs of managing the fund. The benefit may also be influenced by the number of participants drawing from it at any given time. If large numbers of workers were being separated at one time, the benefit might have to be reduced to keep from breaking the fund; whereas, if benefits were being given only in scattered cases, such reduction might not be necessary.

[4] In reality, fringe benefit contributions by the employer may have some advantage to drivers over a direct increase in pay. For income tax purposes an increase in pay becomes immediately taxable whereas employer contributions such as to a severance pay fund would be a fringe benefit not directly taxed. On the other hand, an increase in pay becomes immediately additional earned income whereas severance pay might be only a potential income which would not be received unless an eligible driver were to lose his job.

Table 2. Bargainable ranges of human cost compensation (*HCC*) in productivity bargaining, Minneapolis, 1969–70

| | Status quo | Increased productivity | |
|---|---|---|---|
| Route size: points per day[1] | 3,500 | 5,500 | 7,500 |
| : points per month | 70,000 | 110,000 | 150,000 |
| Absolute maximum:[2] monthly earnings (*AB*)[3] | $1,039.53 | $1,633.50 | $2,227.50 |
| : per unit costs (*AB*)[4] | 1.485 | 1.485 | 1.485 |
| Absolute minimum:[5] monthly earnings (*AD*) | $1,039.53 | $1,039.53 | $1,039.53 |
| : per unit costs (*AD*) | 1.485 | .945 | .693 |
| Actual attainable:[6] | | 25% route reduction capability | |
| route number | 140[7] | 128 | 122 |
| route size—day | 3,500 | 3,829 | 4,017 |
| route size—month | 70,000 | 76,580 | 80,340 |
| Actual earnings, no *HCC* (*AD'*)[8] | — | $1,072.53 | $1,091.33 |
| Actual per unit cost (*AD'*) | | 1.401 | 1.358 |
| Practical maximum *HCC* (*AB-AD'*) | — | $560.97 | $1,136.17 |
| Probability of job loss[9] | — | .086 | .129 |
| Maximum compensating bargainable *HCC* | — | $48.24 | $146.57 |
| Maximum bargainable earnings (*AB'*) | — | $1,120.77 | $1,193.05 |
| Maximum per unit costs (*AB'*) | — | 1.464 | 1.485 |
| Maximum change from status quo: | | | |
| monthly earnings | — | $81.24 | $153.52 |
| per unit cost decrease | — | .021 | 0 |
| Minimum change from status quo: | | | |
| monthly earnings | — | $33.00 | $51.80 |
| per unit cost decrease | — | .084 | .127 |
| Actual attainable: | | 75% route reduction capability | |
| route number | 140 | 103 | 85 |
| route size—day | 3,500 | 4,758 | 5,765 |
| route size—month | 70,000 | 95,160 | 115,300 |
| Actual earnings, no *HCC* (*AD'*) | — | $1,165.33 | $1,266.13 |
| Actual per unit cost (*AD'*) | — | 1.225 | 1.098 |
| Practical maximum *HCC* (*AB-AD'*) | — | $468.17 | $961.37 |
| Probability of job loss | — | .264 | .393 |
| Maximum compensating bargainable *HCC* | — | $123.60 | $377.82 |
| Maximum bargainable earnings (*AB'*) | — | $1,288.93 | $1,643.95 |
| Maximum per unit costs (*AB'*) | — | 1.354 | 1.426 |
| Maximum change from status quo: | | | |
| monthly earnings | — | $249.40 | $604.42 |
| per unit cost decrease | — | .131 | .059 |
| Minimum change from status quo: | | | |
| monthly earnings | — | $125.80 | $226.60 |
| per unit cost decrease | — | .260 | .387 |

[1] A "point" is a quart-equivalent as defined in the labor contract.
[2] All benefits of increased productivity imputed to drivers.
[3] Letters in parentheses refer to curves in Figures 2 and 3.
[4] Per unit costs expressed as cents per point.
[5] All benefits of increased productivity imputed to management.
[6] Under assumed level (25 or 75 percent) of capability for reducing route numbers.
[7] Actual number of routes at time of study.
[8] Figures 2a and 3a represent 25 percent capability; Figures 2b and 3b represent 75 percent capability to reduce route numbers.
[9] Due to reducing number of routes.

70. In a newer or otherwise different contract this point of departure could be considerably different. Actual settlements will be a compromise of some sort within the bargainable limits, as determined by the relative bargaining strengths of the participants.

In Table 2 the *absolute maximum* represents driver earnings and corresponding per-unit costs for the maximum union/minimum management position wherein the union could exact sufficient *HCC* for expanding route size that per-unit costs would remain at 1.485 cents per point (Curve *AB*, Figures 2 and 3). At this extreme all gains accrue to the drivers. The *absolute*

*minimum* represents the earnings and corresponding per unit costs for the maximum management/minimum union position wherein management could expand route size without having to pay more than the current $1,039.53 per month (Curve *AD*, Figures 2 and 3). At this extreme all gains accrue to management.

*Actual attainable* route numbers and volumes depend on management's capability to reduce route numbers if a higher limit on driver daily deliveries were negotiated. Truck capacity, driver capability, traffic, roads, and time available to drivers affect this capability. The extent to which route numbers could actually be reduced determines the *probability of job loss* in this analysis, which is the human cost for which *HCC* is being considered.[5] Assuming a 25 percent capability, a negotiated increase of route size from 3,500 to 5,500 points per day would result in actual route size of only 3,829 points per day (Table 2). This reduction in routes gives a job-loss probability of .086 which, when applied to *practical maximum HCC*, gives a *maximum compensating bargainable HCC* of $48.24. The *maximum bargainable earnings* would be $1,120.77 with a maximum monthly gain to drivers of $81.24 over the status quo. With no *HCC*, the minimum gain to drivers would be $33.00 above status quo due to scale effects of the larger route size. Management would realize a .021 cents per point labor cost decrease at maximum *HCC* and .084 cents per point at zero *HCC*. This indicates that in a Rosow sense both sides *can* win in the productivity bargaining game.

Table 2 shows calculations for two selected route size limits under 25 and 75 percent levels of assumed route reduction capability, giving both monthly earnings and associated per unit costs as the situation would normally be viewed by drivers and management, respectively. Because of limits to actual change in route numbers and due to scale effects, the relevant curves in Figures 2 and 3 become *AB′* and *AD′* rather than *AB* and *AD* which assume unlimited capacity of drivers and trucks, complete divisibility, and full capability to reduce routes.

In this analysis there would be little incentive for management to negotiate a route-size limit greater than 5,500 points per day when the union is relatively strong (settlement close to *AB′*) unless it had more than a 75 percent capability for route number reduction (Figure 2b). On the other hand, a powerful management (settlement close to *AD′*) would tend to find incentive for route expansion at 25 percent or greater capability since *AD′* is decreasing at and above the 25 percent level (Figure 2).

This analysis may explain in part why the driver productivity limit in Minneapolis has endured over a considerable time period. In addition to the inertia of change, the relative power of the union may mean settlement would tend to be close to *AB′*. If management in that market were to view external factors not included in this analysis (costs of larger capacity trucks, for example) as also tending to reduce the incentive to expand, there may be little total

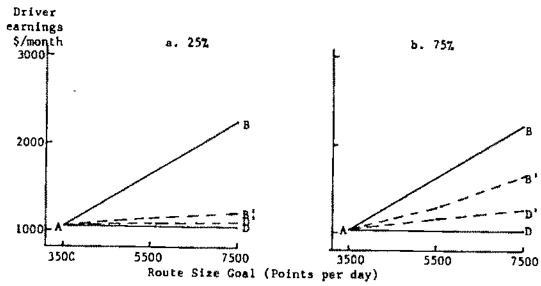


Figure 3. Relationships among driver earnings, route size, and human cost compensation for two increased route size goals at 25 percent and 75 percent levels of capability for reduction in route numbers, Minneapolis, 1969–70

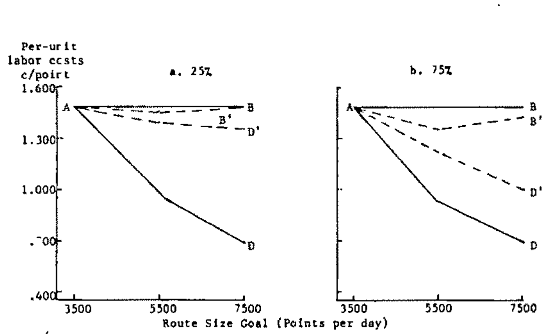


Figure 2. Relationships among per-unit labor costs, route size, and human cost compensation for two increased route size goals at 25 percent and 75 percent levels of capability for reduction in route numbers, Minneapolis, 1969–70

[5] The probability of job loss by drivers when route size is expanded would depend heavily upon the capability of management to effect the delivery of similar total volumes with fewer routes. This would depend in part upon delivery trucks and drivers having excess capacity to haul and to deliver the increased volumes involved. Detailed research has shown definite economies of scale in milk delivery [2, 3] but little on how much capability exists to reduce numbers of routes when route size is increased.

incentive, resulting in continued tolerance of the driver productivity limitation.

## Summary

Increased labor productivity is often accompanied by some form of human cost. Under the premise that such costs should not all be borne by workers, sharing is implied. Productivity bargaining gives a framework for sharing the benefits of technological innovation. This paper gives an application of this approach to determine ranges in human cost compensation that could be bargained for in relaxing an actual productivity restriction. Final determination of the compensation for human costs is, however, left to be bargained, thereby preserving a basic tenet of the collective bargaining process. The analysis points out a rational explanation of the prolonged existence of a prominent restriction on labor productivity in fluid milk delivery.

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# Farm Population Decline and the Income of Rural Families*

Bruce L. Gardner

**The effects of farm population decline on median rural family incomes in states and counties are estimated. Farm population decline is found to be associated with increases in incomes of rural farm families and to have no long term effect on incomes of rural non-farm families.**

***Key words:*** **income; population.**

Economists have been concerned for many years about the consequences of a declining farm population for the economic status of the people remaining in rural areas [2, 3, 5, 6, 8]. This concern is apparent also among policy-makers, for example, in the hearings and debate on the Rural Development Act of 1972. The prevailing sentiment in Congress appears to be that rural-to-urban migration has been in some sense excessive and that public policies to slow down this movement would be beneficial. This sentiment is based partly at least on the acceptance of a hypothesis that farm population decline has not improved, and has probably harmed, the economic well-being of the people remaining in rural areas.[1] This paper is an attempt to bring some evidence to bear on this hypothesis.

## Problems in Applying Economic Theory

The Report of President's National Advisory Commission on Rural Poverty says: "The mass exodus from low income rural areas in recent years has meant that those left behind are often worse off than before" [5, p. 6]. But the report does not cite any theoretical arguments or empirical evidence to support this proposition. There is good reason for this omission. The theoretical arguments that exist in the literature are quite sketchy, and the empirical evidence is even more so. Before examination of the evidence from state and county data, some theoretical approaches are discussed.

Rural population decline is, of course, not an independent event which influences economic conditions in rural areas but rather is mutually determined with these conditions. Therefore, it is necessary first to discuss the system of economic relationships within which rural population decline is observed. A two-sector general equilibrium model, containing a rural and urban sector, provides one possible tool of analysis. In such a model a shift in demand away from farm products, or faster technical progress in the rural sector, will induce rural-to-urban movements of resources. But in such a model there is no *a priori* reason for rural population decline to have any particular implications for the incomes of the people left behind. The results depend on what induced the decline, what non-human resources the migrants take with them, and whether urban-owned non-human resources move into rural areas.[2]

The existing literature on the consequences of rural population decline [2, 3, 5, 6, 8] does not make use of the general equilibrium approach. Rather, migration is seen as a phenomenon characteristic of *disequilibrium*, in the sense that factor prices and income of comparable individuals are unequal in the two sectors. In this context several hypotheses have been developed as to why farm population decline should affect the incomes of remaining rural people.

The first is that out-migration sets into motion a kind of local recession which reduces the well-being of the whole rural community as aggregate demand in the community declines.[3] This hypothesis could serve as a foundation for the pessimism of the Commission on Rural Poverty. Second, there is the view that out-migration of farmers is the process of correcting a state of

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[1] A representative statement from the House debate, by Representative Clausen, is the following: "I think reasonable men will agree that the impact of this mass movement to the central city has not been beneficial either to the places from which these migrants have come or to the places where they go" [9, p. H1336]. See also the testimony before the Senate Agriculture Committee, April 29, 1971.

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[2] See the discussion of analogous issues in the context of international migration in [1].

[3] See [8, p. 111] for such an argument.

disequilibrium—"too many farmers"—and that therefore reduced farm population should lead to *higher* incomes for remaining farm operators as the excess supply is eliminated.[4] The first hypothesis treats population decline essentially as a creator of disequilibrium, the second as an ameliorator of disequilibrium. Third, it has often been pointed out that to the extent that economies of size exist in the provision of public services, their cost will be increased when population declines.[5]

The purpose of this paper is to investigate what the connection between population decline and rural well-being has been. This is done by comparing states and counties that vary in their rates of historical farm population loss. The usefulness of the theoretical considerations outlined above is that they help in interpreting what is observed and in deciding what should be held constant to make the most meaningful comparisons between diverse areas.

Since the only cross-sectional data available that can serve as a reasonable indicator of rural well-being pertain to incomes of individuals and families, this paper does not consider the third aspect—public services—mentioned above. It concentrates on evidence bearing on the "local recession" and "adjustment-to-disequilibrium" views of farm population decline. The fact that the first of these applies mainly to rural nonfarm people and the second to rural farm people suggests treating these two groups separately. Rural farm families are considered first.

## Out-Migration and Rural Farm Income

During the decade of the 1960's the median income of U. S. rural farm families rose from $3230 to $7080, while the number of rural farm families fell from 3.3 to 2.2 million. Did the increase in income occur despite or because of the population decline? The second hypothesis above suggests that out-migration of farmers contributed to the increase in income—that rural farm income would have risen less rapidly if more people had remained in farming. One way to get evidence on this question is to compare the income growth of states that varied in their rates of farm population loss by means of a simple cross-sectional regression. If the states that lost farmers most rapidly had the most rapid income growth, there is evidence in favor of the adjustment-to-disequilibrium hypothesis. However, listed below are reasons why such a simple regression may not be the best way to investigate this hypothesis.

### Selectivity of migration

It would not be expected that the families that disappear from the farm population are a random or representative sample. Therefore, farm population decline can result in increased (decreased) rural-farm incomes in a state simply because poorly (well) endowed individuals migrate. But the adjustment-to-disequilibrium hypothesis does not rely on the representativeness of migrants. It predicts higher rural-farm income with increased out-migration even if the characteristics of the rural farm population remain unchanged. This suggests that the empirical treatment should hold important income-yielding characteristics constant.

### Non-human resources

The economic mechanism by which out-migration is hypothesized to ameliorate disequilibrium has two aspects: a reduction of human resources in farming, hence reduced agricultural output and increased product prices; and an increase in non-human resources per farm family. Because non-human resources can move independently of farm operators, the model should include the non-human resources on farms in order to isolate the effects of labor migration.

### Off-farm work

The problem off-farm work raises is that the states declining most in farm population may be increasing most rapidly in off-farm work by rural-farm residents. In this case an observed positive effect of farm population decline on income could be due simply to correlation with the left-out variable, off-farm work.

To take account of this possibility, it is necessary to distinguish two ways of engaging in off-farm work. First, a farm operator can take a nonfarm job and cease his farm operation while retaining his rural residence. If he does this, he disappears from the census rural-farm population even though he has not moved. Therefore, this first kind of off-farm work is already included in "farm population decline" as measured by census data.

The second means of engaging in off-farm work is to continue farm operation at least sufficiently to be classified "rural farm" by the Bureau of the Census while working at an off-farm job. This kind of off-farm work has been increasing

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[4] [2] provides an analytical basis for this view.

[5] See the discussion in [3].

in the 1960–70 period.[6] But this form of occupational mobility is excluded from the empirical model as discussed thus far even though the off-farm income of farm families is included in the census measure of rural farm family income. A correctly specified model should include the off-farm work of farm operators and other members of rural-farm families.

### Mutual dependence of migration and income

The discussion to this point leads to multiple regression instead of simple cross-sectional correlation. But an econometric problem still exists because out-migration is probably a function of changes in income, as well as changes in income being a function of out-migration. This mutual determination will produce simultaneous-equation bias in the coefficient of farm population decline. Since the expected sign of income in the left-out structural equation determining out-migration is negative (higher farm income yielding less out-migration), the bias in a positive ordinary least squares (OLS) migration coefficient is toward zero. Accounting for this mutual dependence requires simultaneous equation estimation techniques. For this purpose two-stage least squares (TLS) is used. Details are given in the footnotes to Table 1.

### The data

Data on the average age and schooling of the rural-farm population are used to hold constant characteristics that might be changed as a result of the migration process. Agricultural non-human resources are measured as the value of land and buildings.[7] Finally, days worked on nonfarm jobs by farm operators are used to measure off-farm work. These data are all available in the published reports of the U. S. *Census of Population* [11] and *Census of Agriculture* [10]. Specific sources are given in the footnotes to Table 1.

[6] The mean of the state data was a 24 percent increase in days worked off the farm by farm operators between 1959 and 1969.

[7] According to Melichar [4, p. 316], real estate accounts for over 70 percent of farm non-human resources as of 1970.

Table 1. Regression coefficients: dependent variable, annual rate of change of state median rural farm family income, 1970/1960

| Type of regression (N=48) | Independent variables: 1970/60 annual percentage changes[a] | | | | | |
|---|---|---|---|---|---|---|
| | Farm Population Decline | Schooling | Age | Land and Buildings | Off-farm Work | $R^2$ |
| 1. OLS | .31 | | | | | .19 |
| | (3.2)[b] | | | | | |
| 2. OLS | .30 | .26 | 1.8 | | | .26 |
| | (3.3) | (1.3) | (1.7) | | | |
| 3. OLS | .32 | .29 | 1.2 | .35 | | .40 |
| | (3.9) | (1.5) | (1.2) | (3.3) | | |
| 4. OLS | .40 | .25 | 0.2 | .48 | .23 | .46 |
| | (4.5) | (1.3) | (0.2) | (3.4) | (2.1) | |
| 5. TLS | .88[c] | .27 | 1.1 | .40 | | (.59) |
| | (6.3) | (1.7) | (1.3) | (4.4) | | |
| Means (dep. var.: .083) | .036 | .021 | .001 | .054 | .024 | |

[a] Sources of data: median rural farm family income and number of farm families [11], Table 200 (1970) and Table 65 (1960); median schooling of rural-farm males aged 25 and over [11], Table 47 (1960) and Table 197 (1970); average age of farm operator, aggregate value of land and buildings, and days worked off farm by farm operators [10].

[b] Numbers in parentheses are "*t*" ratios.

[c] Farm population decline in this regression is the predicted value from a reduced form equation having as exogenous variables schooling, age, and land and buildings, plus the state's average wage rate in manufacturing adjusted for unemployment by multiplying by 1 minus the state's unemployment rate, following Schuh [7].

The estimated reduced form equations for farm population decline ($\hat{Y}_1$) and the change in rural farm income ($\hat{Y}_2$) are:

$\hat{Y}_1 = -.03 + .13$ (Schooling) $-.38$ (Age) $-.24$ (Land + Bldgs.) $+ 1.91$ (Wage).

$\hat{Y}_2 = -.01 + .39$ (Schooling) $+ .72$ (Age) $+ .19$ (Land + Bldgs.) $+ 1.69$ (Wage).

The other structural equation (farm population decline is dependent variable) is:

$Y_1 = -.03 - .37\,(\hat{Y}_2) + 2.4$ (Wage).

## Regression results

Table 1 presents regression results on state data for the 1960–70 period. The table shows the final TLS equation and the simple regression and multiple OLS regressions which successively add the variables discussed above. Various specifications are shown because the formulation of the empirical model, though it brings aspects of economic theory to bear, is not a rigorous theoretical treatment. In addition there are the usual problems that the census data do not correspond exactly to what one wants to measure and probably contain measurement errors, and there are probably left-out variables correlated with the included ones. In these circumstances the best test is probably the robustness of the relationship between farm population decline and rural-farm income under alternative specifications. Finally it is not clear that for the purposes of policy-makers a *ceteris paribus* regression coefficient is much more useful than the simple regression which lets other things change as they will.

As it turns out, the consistently positive sign on farm population decline indicates that for either the simple regression or any of the more complicated specifications, faster rural-farm population decline is associated with faster growth of rural-farm family income.

Other tests of this relationship not shown in Table 1 were also done. These are: (1) regressions specified the same as in Table 1 but using county data (the sample of counties to be discussed in the following section); (2) the same regressions on 1960/1950 data; and (3) regressions having the 1970 *level* rather than 1970/1960 changes as dependent variable. All these additional sets of tests show also a positive effect of out-migration on the incomes of the rural-farm people left behind.

In sum, the positive relationship between greater farm population decline and rural-farm incomes is robust with respect to time period considered, level of aggregation of the observations, and specification of the regressions. It seems that U. S. out-migration from agriculture in the post-World War II period has in fact been beneficial to the remaining rural-farm population.

## Consequences of Farm Population Loss for Rural Nonfarm Families

The theoretical argument for out-migration of farm operators being beneficial to the remaining farm families is based on the function of migration as an equilibrating device. The argument that out-migration harms the rural community, on the other hand, treats migration as a creator of disequilibrium. This disrupting aspect of migration is widely recognized among policy makers. For example, Congressman Poage, in the debate on the 1972 Rural Development Act, said: "When these people leave our farms, we see the local economy of our small towns suffer. What happens to the banker, the grocer, the doctor, the implement dealer, and even to the churches? They all suffer . . ." [9, p. H1332].

It seems evident that to the extent that farm population decline reduces the demand for services provided in rural towns, owners of fixed resources will lose rents and quasi-rents in the activities supplying these services. The question is, how many of these losses will occur only in the short run, and how many, if any, will persist in the long run? The answer depends on the occupational and residential mobility of the nonfarm population in rural areas. If the resources for which demand has declined are perfectly mobile, their owners will experience no long-run income decline. But even in this case losses may be substantial if "the long run" is very long. In this paper inter-censal (10-year) changes are considered.

Even if rural nonfarm resources are immobile, it is not certain that the demand for the services provided by rural towns will decline when farmers migrate. There will be fewer farm families, but their incomes will be greater if the results of the preceding section are correct. Therefore, the community's demand for products with high income elasticities may actually increase. Thus the extent of mobility of nonfarm people required depends on the kinds of goods and services provided locally. In short, it seems impossible to say *a priori* whether remaining nonfarm residents of rural areas will suffer income declines as a result of a continuing trend of out-migration from agriculture.

## Regression analysis

The effects of farm population decline on rural nonfarm people can be investigated empirically by further comparisons of areas that vary in their rates of farm population loss. The measure of loss or gain is again median family income.

Regression 6 of Table 2 shows a simple regression coefficient of farm population decline on growth in median rural nonfarm family income. The coefficient is positive, which indicates that rural nonfarm incomes grew *more* rapidly the

Table 2. Regression coefficients: dependent variable, 1970/1960 changes in median rural nonfarm family income

| Regression Number | Independent Variables[a]: Farm Population Decline | Schooling | Age | Alternative Wage | Median Farm Income | $R^2$ |
|---|---|---|---|---|---|---|
| *State data:* | | | | | | |
| 6 | .16 | | | | | .19 |
| | (3.3)[b] | | | | | |
| 7 | .01 | 1.02 | .001 | .26 | .40 | .79 |
| | (0.4) | (1.2) | (0.1) | (6.0) | (2.6) | |
| *County data:* | | | | | | |
| 8 | .13 | | | | | .08 |
| (199 counties) | (3.6) | | | | | |
| 9 | .01 | 1.29 | | .48 | .32 | .48 |
| (199 counties) | (0.3) | (5.0) | | (4.8) | (6.5) | |
| 10 | .01 | 2.27 | | .40 | .30 | .50 |
| (93 "most rural" counties) | (0.2) | (5.2) | | (3.3) | (4.2) | |
| 11 | —.08 | 2.28 | | .49 | .20 | .67 |
| (33 "most rural" counties) | (1.0) | (3.4) | | (3.6) | (1.7) | |

[a] Sources of data: "Farm population decline," "median farm income," and "alternative wage," same as in Table 1; "schooling" and "age" are medians for rural nonfarm males aged 25 and over [11], Tables 37 and 47 (1960) and Tables 48 and 51 (1970); County data: Tables 91 and 93 (1960) and Table 134 (1970).

[b] "$t$" ratios are in parentheses.

faster the farm population fell. This is the opposite of what the "local recession" argument predicts.

One possible explanation of this result is that the direction of causality is not from farm population decline to faster growing nonfarm income, but rather from faster growing nonfarm incomes to greater population decline. However, this reverse causation would not be a response of farm residents to rural nonfarm incomes specifically, but rather to the opportunities rural farm people have for earning income in nonfarm jobs compared to their earnings in farming. These nonfarm opportunities presumably are more closely related to the state's wage rates and rate of unemployment in the nonfarm sector than to median rural nonfarm incomes. Regression 7 is an attempt to hold nonfarm opportunities constant by using the state's mean wage rate in manufacturing. This wage rate is adjusted for unemployment as in Schuh [7]. Median rural farm family income is also included as an independent variable to hold constant the earnings given up to migrate. In this more complete specification, the coefficient of farm population decline becomes insignificantly different from zero.

It is possible that states are too large as units of observation for investigating the consequences of farm population loss on rural nonfarm people. Especially in the more urbanized states, the rural nonfarm population is probably more closely connected economically with urban than with farm conditions. But if all the substantially urbanized states are eliminated, there are not enough observations left for a meaningful empirical investigation. Therefore, a sample of counties was drawn for further regression analysis.

In addition to providing more observations, counties have the advantage that the effects of off-farm migration on the rural nonfarm population may be easier to detect in smaller aggregates. But for counties, as for states, the extent of this effect is expected to vary with location *vis-à-vis* urbanized areas. A sample of 199 noncontiguous counties was constructed to yield factor market areas and rural communities as nearly distinct as possible. The sample was divided into five subsamples: (1) counties having zero urban population and not adjacent to any county containing a city of 25,000 or more people as of 1960 (33 counties); (2) counties having at least one town of over 2,500 but less than 25,000 population, otherwise like group (1) (60 counties); (3) counties either containing a city of 25,000 or more or adjacent to such a county (23 counties); (4) counties adjacent to a standard metropolitan statistical area (59 counties); and (5) counties within an SMSA

(22 counties). Any county that fits in more than one of these categories was assigned to the higher-numbered (more urbanized) group.

To investigate whether location with respect to urbanized areas made any substantial difference in how the income of a county's rural nonfarm population was affected by out-migration, separate regressions were run for each of the five classes of counties. Results for the two "most rural" classes, (1) and (2), are shown as regressions 10 and 11 in Table 2. In no case was the coefficient of farm population decline statistically significant. Group (1) counties had a small negative coefficient on farm population decline, but even here one cannot reject the hypothesis of a zero coefficient.

## Meaning of the results

The regression results of Table 2 imply that, on the average, remaining rural nonfarm families do not suffer reductions in income associated with farm population decline given a 10-year adjustment period. They do not imply, however, that no losses have been imposed on rural nonfarm people. In the short run, off-farm migration could well have created disequilibria that resulted in transitory losses. But apparently the rural nonfarm population is occupationally mobile enough to adjust completely over a 10-year period, with the possible exception of the counties most isolated from urban areas.

It should also be recalled that the analysis has not dealt with the public-sector consequences of rural population decline mentioned at the beginning of the paper. The decreasing density of rural population presumably increases the costs per family of such things as schooling and fire protection.[8] There might also be nonpecuniary costs of declining population. It should be noted, though, that if rural nonfarm people are mobile enough to eliminate pecuniary disadvantages compared to their best alternatives, there is no *prima facie* reason why they should not be mobile enough to equate marginal net amenities between rural and non-rural living.

[8] The fact that the losses are greatest in the area of publicly provided goods suggests that politicians might see population decline less favorably than private citizens. This may reconcile the relatively benign findings of this paper with the alarm of the political figures in the Congressional testimony and debate cited above.

Table 3. Rates of growth of rural median family income

| | Compound annual rates of: | | |
|---|---|---|---|
| | Farm pop. loss | Growth of farm income | Growth of rural nonfarm income |
| Ten fastest-declining states | 7.4 | 9.5 | 6.2 |
| Ten slowest-declining states | 2.4 | 8.0 | 5.4 |
| Mean of all states | 4.7 | 8.4 | 5.7 |

## Summary and Conclusion

The basic data for the decade of the 1960's that this paper works with are summarized in Table 3. Table 3 presents the same message as the simple regressions of Tables 1 and 2; the rate of a state's farm population loss is positively associated with the rate of growth of average income. The more complicated empirical analyses, which were attempts to hold other economically relevant variables constant, did not change the positive association with rural farm income but eliminated the association with rural nonfarm income. In neither case was there evidence of long-term adverse effects of farm population decline on family incomes in rural areas. Thus it appears that the pessimism of the President's Commission on Rural Poverty and of many policy-makers concerning the economic consequences for rural areas of continuing off-farm migration may be unjustified.

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# Agricultural Districts: A Compromise Approach to Agricultural Preservation

H. E. Conklin and W. R. Bryant

**New York's Agricultural District Law contains a series of interrelated provisions designed to encourage the continuance of agriculture under conditions in which urban scatteration and consequent speculation would otherwise prematurely destroy it. Other states with similar rural land use problems may find New York's experience helpful.**

*Key words:* **rural land use policy; urbanization; speculation; land conversion; agricultural preservation; agricultural zoning; farm-value assessment.**

LAND USE PLANNING has emerged as a prominent issue on both state and national levels. In what has been termed "the quiet revolution in land use controls," one state after another has passed legislation to regulate the use of its wetland, shoreland, farmland, waterways, and other areas considered to be critical to the environment [3]. Legislation to establish a nationwide land use planning and control process was considered by Congress in 1973 [2].

The transfer of large amounts of land from agriculture to urban uses has been an increasing concern of land use specialists in the United States since shortly after World War II [9, 19]. During the 1950's and 1960's this country experienced unprecedented growth in population numbers, per capita incomes, new household formations, and construction activity. In that period it became distinctly more urban in character. The widespread building of electric lines, improvements in cars and roads, and the more complete development of individual home sewage disposal systems contributed to vast suburban expansions and the widespread dispersal of single-family detached dwellings into rural areas beyond the suburbs [1]. Much productive farmland, particularly in areas proximate to the northeastern megalopolis, either was bought directly out of agriculture for new urban uses or was engulfed by a speculative surge that accompanied the growth and scatteration of urban populations.

Most state legislatures dealing with the problem of farmland preservation have adopted farm-value assessment laws [11, 13].[1] In Hawaii, however, the state undertook to protect agriculture by zoning land exclusively for that purpose.[2] Both farm-value assessment of farmland and state zoning were considered in New York as means for sustaining a viable agriculture, but both failed to be enacted as law. A proposal for agricultural districts evolved as a compromise that proved to be politically feasible.

New York's agricultural district program provides some innovative concepts in rural land use policy. Districting starts with local initiative and involves interaction among farmers, nonfarm people, local government, and state government. Provisions of the law encourage farming and discourage other uses within the districts but do not involve direct control of land use through the police power. The goal sought is to keep good farmland in farming until it really is needed for other purposes; in other words, to block the destructive impact of speculation on farming but not to make permanent city parks out of farmland. The purpose of this paper is to sketch briefly the rural land use situation in New York and then to discuss the Agricultural District Law and the role it is intended to play in promoting continued agriculture in the state.

## Extent of Agriculture in New York

Though New York has the second largest population of any state, only about 10 percent of its area is in cities or suburban concentrations with their interconnecting transport net. Only about one-fifth of the state is in full-time farming, but the value of farm products exceeds a billion dollars per year and is higher than at any point

[1] Farm-value assessment laws have been placed in three classes by Hady [12]: preferential assessment, deferred taxation, and restrictive agreement. Questions have been raised as to the effectiveness of these laws as land use control mechanisms [12, p. 32].

[2] Act 187, SLH 1961 (State Laws of Hawaii). Hawaii's atypical land use control program established four zoning districts—conservation, agricultural, rural, and urban. Each parcel of land in the state was placed in one of these.

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in history. New York ranks nineteenth among all states in value of farm output and second in cash receipts from dairying [20].

## Current Rural Land Use Picture

### Urban scatteration

With a population of 18.5 million and only 10 percent of the state's land now urban, with the current slowing in population growth, and with national migration tending to move people south and west, it will be many decades before even as much as 20 percent of New York's land is urban. Urban growth for many years could find ample space by filling in blank parcels within semi-urbanized areas adjacent to present cities and closely built suburbs. Beyond that there are some 20 million acres in the state that are neither in full-time farms nor in cities. There is no imperative urban demand for good farmland.

But urban scatteration still is continuing in patterns that extend beyond the boundaries of the semi-suburbs and that often "sterilize" many times as much farmland as they actually occupy. A high degree of affluence has made it possible for people to live in the open country and commute to urban employment. And this progressively growing demand now is being augmented by a quest for recreational and retirement properties and by a strong urge to buy land as a hedge against inflation, though much of the recreational and hedging demand to date has been directed primarily toward nonfarm lands. This present interest in rural land, coming as it does on the heels of two decades of unprecedented urban growth and scatteration, is producing a sharp bulge in speculative expectations.

### Speculation

Clawson and others have stressed the fact that lack of understanding and knowledge about the land conversion process have contributed to speculative anticipations in rural areas [5, p. 120–121; 8]. The tendency for that portion of an area that passes to urban uses to do so at prices far above farm value when farming is the next alternative use appears to be anomalous within economics in the Kuhnian sense [16, p. 52–66]. But whether economically anomalous or not, this phenomenon seems to play a significant role in speculation and therefore seems important in designing instruments to ameliorate speculative impacts.

Speculative conditions in which some though not all of an area will sell at high prices and in which the high priced sales seem to occur in unpredictable patterns increase the degree of uncertainty under which the farmer must make his investment decisions. This is especially true where the type of farming involves heavy investments in real estate improvements that become rapidly obsolete, as in dairying or tree-fruit production, and that have little or no value for nonfarm purposes [8].

A sequence of nearly irreversible changes in total agricultural activity occurs in a community once speculative influences are present. Speculation not only discourages continuance of the flow of needed new investment into farming but also discourages investments in agribusinesses that are needed to service farming. Gradually confidence and interest in farming deteriorate. The encroaching scattered urban activities bring new patterns of life that further inhibit farm use even of the lands for which farming would be the only possibly feasible productive activity for years to come.

Knight points out that generally a degree of specialization emerges in speculative situations [15, p. 259]. Professional speculators enter and take over the risk and uncertainty bearing while another group conducts the physically productive activities involving the resource concerned. If the resource is land, the specialization involves purchase of the land by the speculators and its rental by farmers. This arrangement, however, is not feasible in many farm areas of New York. Since the speculative specialists wish to retain a high degree of flexibility in their dealings, they do not wish to invest in the expensive improvements needed to maintain active farming. They often will not even sign leases that are long enough to justify lime applications, drainage improvements, and other shorter term investments needed just for crop growing.

## Initial Farmland Preservation Efforts

### State zoning

There has been a growing concern with problems of rural land use in New York, including those related to agriculture, for many years [7]. In 1966 the state created the Office of Planning Coordination (OPC) which developed a proposal for thoroughly restructuring the planning and land use control laws of the state. Their final proposal would have shifted planning and land use control functions from lower to higher levels of government and from lay to professional

people. Although introduced as a study bill in 1970, this proposal never came to a vote.[3]

If passed, OPC's proposal would have provided for the zoning of "areas of critical state concern." All major farming areas of the state would have been included in these areas. The police power could have been used at the state level, if judged necessary, to prevent further encroachment of urban uses onto farmlands.

### Farm-value assessment

Farm-value assessment bills were passed by the New York State legislature in 1965 and 1966. These bills were promoted by farm organizations and were patterned closely after the farmland assessment law that had been put into effect in New Jersey a few years earlier. Both of these bills were opposed by many persons in state and local government and were vetoed by the governor.

### Agricultural Resources Commission

Soon after vetoing the special farm assessment bills, the governor created the Commission on the Preservation of Agricultural Land to explore a wide range of matters related to the continuance of agriculture in the state. That commission was replaced in 1968 by a permanent body, the Agricultural Resources Commission (ARC) [6].

The Agricultural Resources Commission viewed its task as one of creating proposals that would help to restore the faith of farm people in farming where speculation has eroded it, help to dull the impact of speculation-stimulated changes in levels of taxation and in local and state regulations of various types, and help in general to discourage urban scatteration in good farm areas where there is no near-term prospect for wall-to-wall urbanization. In a state where alternative employment opportunities are plentiful, ARC has emphasized that the future of agriculture is heavily dependent on the attitudes of farm people.

### Five year tax exemption

In 1968 the legislature passed ARC-sponsored legislation which amended the state's real property tax law to permit farmers to obtain a five year property tax exemption for improvements in farm real estate.[4] This proposal was acceptable, while the farm-value assessment proposals were not, principally because it would be more difficult for speculators to use this law as a means of facilitating their speculative activities. Research on the preliminary effects of this law indicates that it has stimulated new farm investments in many areas [17].

The Agricultural Resources Commission also recommended the proposal for legislation that would permit the formation of special districts, to be known as agricultural districts, in areas well adapted to farming.[5] This proposal was passed unanimously by the 1971 session of the legislature and became effective in September of that year [4].

## Agricultural Districts

### Forming a district

The process of forming an agricultural district starts with local initiative. One or more farmers usually spend a number of days contacting other farmers and nonfarm landowners, obtaining their signatures on the request for the district (not all landowners need to favor a district to be included in it, however). Preliminary maps must also be prepared at this time.

After farmers and other landowners have completed the initial steps, the district proposal is submitted to the county legislative body which in turn refers it to its planning board and its agricultural advisory committee for consideration. The agricultural advisory committee and the county planning board report their recommendations to the county legislature, one or more public hearings are held on the proposal, and the county legislature may then accept it, or a modification, for referral to the State Commissioner of Environmental Conservation.

The Commissioner of Environmental Conservation acts on the district proposal after he receives recommendations from the Agricultural Resources Commission and the Office of Planning Services. State inspectors examine each proposed district in the field and prepare reports on the nature of farming and urban influences in the area. The district must be consistent with state comprehensive plans, policies, and objectives. When the state review process is completed,

[3] This proposal, referred to as Senate Bill 9028, was inconsistent with long standing tradition and values deeply held by many people in the state. An interesting sidelight to this story is the fact that OPC had its budget cut by 60 percent and its name changed to Office of Planning Services (OPS) after it recommended this proposal.

[4] Ch. 1092, SLNY 1968 (State Laws of New York).

[5] Ch. 479, SLNY 1971, Ch. 700 and 712, SLNY 1972, and Ch. 232 and 390, SLNY 1973.

the Commissioner may certify the proposal, or a modification, as eligible for adoption as a district.

Returning to the local level, the proposal must receive final action by the county legislature. Another public hearing may be held at this time. If the original district plan was modified by the state, this hearing is compulsory. Should the county legislature decide to take no action, the proposal automatically becomes effective as a district within a specified period.

The formation of an agricultural district is a cumbersome and time consuming process. It usually takes more than six months from the start of efforts to the final creation of a district as a legal entity. The cumbersomeness of the process, however, has provided interaction which has increased public awareness of the importance of agriculture and of the significance of agricultural districts. Legislators, planners, rural landowners, and others must get involved in forming districts at the local level. The state review process provides for involvement by several state agencies.

Beginning in 1974, the state may create agricultural districts of 2,000 acres or more to encompass "unique and irreplaceable" agricultural lands. To do so, however, requires initial steps by the Agricultural Resources Commission and action or agreement by several other state agencies. The law also states that the cooperation of local people must be elicited. This provision of the Agricultural District Law was included at the request of agricultural interests who feared that proposals for the creation of agricultural districts would not be sympathetically accepted by county legislatures. To date very few requests for districts have been turned down by county legislatures, and state action to form districts is likely to be very limited.

## Summary of provisions

Whether created by a county legislature or by the state, the following provisions apply within all districts:

1. *Farm Assessments*—Farmers may apply annually for an exemption from taxation on the value of their land in excess of its value for farming. To be eligible, a farmer must own 10 or more acres of land used the preceding two years for agricultural production having a gross sales value of \$10,000 or more. Farmland which has received an exemption is subject to a maximum five year rollback if converted to a nonfarm use. This provision of the law legitimizes a long standing farm assessment practice in New York which is threatened to be lost because of the passage of a new assessment law in 1970 [18].[6]
2. *Ordinances*—Local governments may not enact ordinances that would restrict or regulate farm structures or farm practices beyond the requirements of health and safety.
3. *State Regulations*—State agencies must modify administrative regulations and procedures to encourage the maintenance of commercial agriculture to the extent compatible with health, safety, and any applicable federal regulations.

4a. *Eminent Domain*—The right of public agencies to acquire farmland by eminent domain is modified, though not removed. These agencies are required to give serious consideration to alternative areas before good farmland can be taken for public uses.

4b. *Development Funds*—The right of public agencies to advance funds for sewer, water, and other facilities that would encourage nonfarm development is modified.

5. *Special Service Assessments*—The power of special districts to impose benefit assessments or special *ad valorem* levies on farmland for sewer, water, lights, and nonfarm drainage is limited.

The Agricultural District Law also provides that each district must be re-examined by the county and state each eight years. If a portion of a district is in strong demand for nonfarm uses, the county and state may change the district boundary at the next eight year review. Boundary changes, however, can be made only at eight year intervals. The county and state have authority to continue any district indefinitely, regardless of local wishes.

Individual farmers who are not in a district are provided the opportunity to benefit from the farm assessment provision of the law. They must file an agricultural commitment and commit their land, in writing, to farming for eight years. Each year they must recommit it for the next eight years. If land in a commitment is converted to a nonfarm use while the commitment is still in effect, it is subject to a large penalty, instead of a rollback. This penalty is two times the taxes

[6] Ch. 957, SLNY 1970.

determined for all land previously under commitment for the year following the breach and is added to the amount of taxes determined for that year. In other words, previously committed land which is converted during the period of commitment is subject to three times the amount of taxes determined for the year following the breach of commitment. Few farmers to date have asked for commitments.

### Non-authoritarian approach

Exercise of the police power has been the predominate land use control mechanism used in the United States [10]. It has been used predominately by local governments to control certain land uses in urban areas. In recent years, however, there has been a growing tendency to use the police power at higher levels of government to regulate all types of land use [3].

Agricultural districting appears to be a rather "soft" non-authoritarian approach to land use control when compared to the absolutes of police power. Nonfarm houses can be built in districts, though developers are likely to go elsewhere due to problems of financing sewer and water services. Government agencies can take land in districts, though they have to explain why they cannot place their roads, dams, and buildings, on alternative sites. Serious farmers—those for whom the value of gross farm output equals or exceeds $10,000 per year—are assured that property taxes will not preclude their operation. Local governments are enjoined from restricting farming for the purpose of encouraging other uses, and state agencies are instructed to encourage farming in districts, but these are not as forceful as the police power.

### Rededication to farming

When farmers draw the boundaries for an agricultural district around their land, they are, in a sense, rededicating themselves to farming and reassuring each other that they want their community to remain in agriculture. Once this group action is taken, the agricultural district program provides a package of interrelated provisions designed to protect farmers from rising costs, governmental actions, or other concomitants resulting from urban scatteration and to divert nonfarm activities to areas not suited for farming. With the uncertainty associated with continued farming reduced, farmers are willing to make the investments necessary to keep their operations competitive. Active farming in turn encourages agribusinessmen to maintain aggressive investment policies.

### Snowball effect

The very fact that large numbers of people expect agricultural districts to be effective increases the likelihood of their effectiveness. Initial investment and location decisions and personal commitments by farm and nonfarm people alike in anticipation of district effectiveness can start processes that will tend to be reinforced by subsequent decisions, providing a snowball effect. It is possible that special life patterns will gradually emerge in districts and that people who prefer farming as a way of life will concentrate in these areas.

### Progress to date

On January 1, 1974, slightly more than two years after the Agricultural District Law went into effect, there were 117 districts formed or in the late stages of formation. These districts total nearly one million acres, or approximately one-fifth of New York's full-time farmland, and are located in all major agricultural areas except those nearest to New York City, such as Long Island.[7] As Figure 1 shows, several of the districts are located in areas close to major upstate cities and some are in distinctly rural areas, but a noticeable concentration exists in an area of particularly high speculative pressure about 100 miles north of New York City.

## Summary

Although it may be 10 years before it can be adequately evaluated, New York's agricultural district program has been highly effective to date in involving large numbers of people in the processes it has set in motion in all major agricultural areas of the state except those nearest to New York City. It promises to spark the kind of free but concerted action that can snowball into a movement for encouraging continued agricultural production in areas where scattered nonfarm uses and speculation would otherwise result in a premature decline in farming activity.

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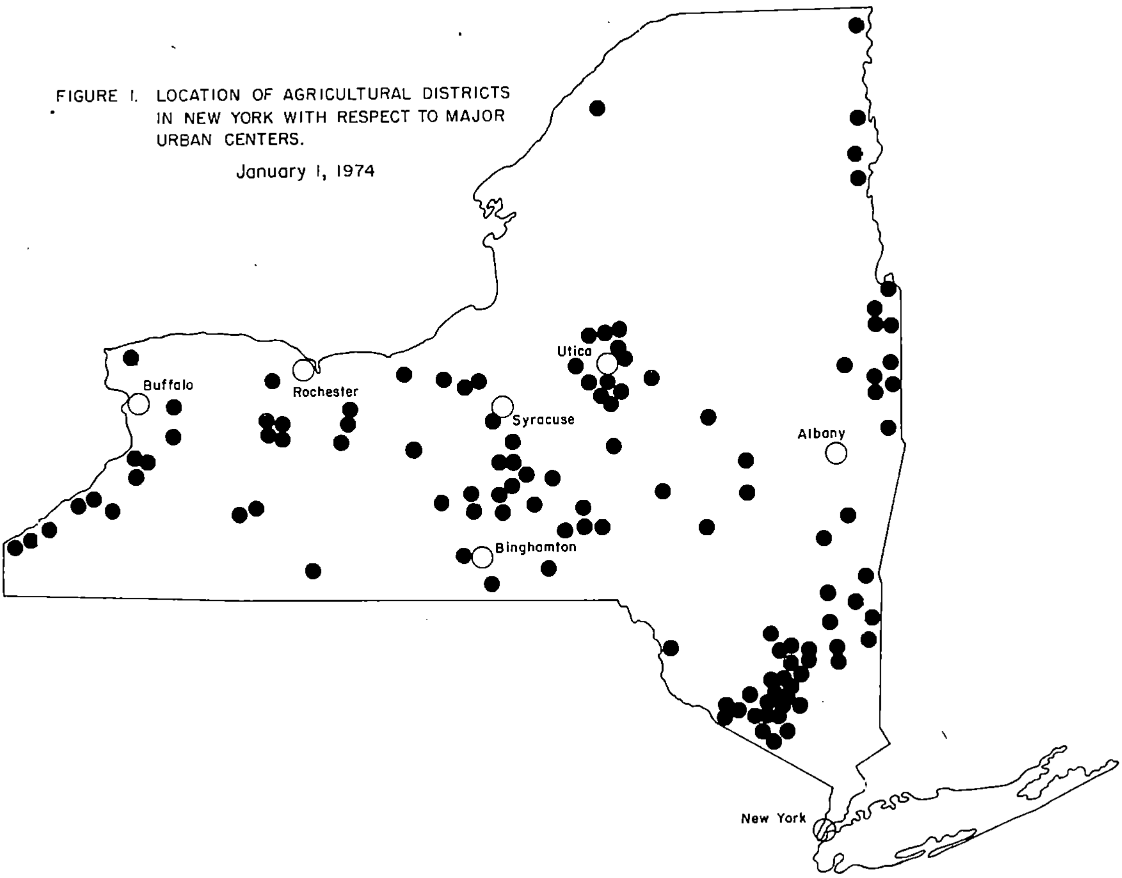
[7] One county on Long Island, Suffolk County, has included $45,000,000 in its 1974–1976 budget for the preservation of farmland in the eastern part of the county. A combination of the acquisition of fee title with leaseback to farmers and the acquisition of development rights with the right to continue farming maintained by farmers will be used to set aside land for agricultural purposes [14].




In areas of imminent wall-to-wall urban development, however, it appears that some type of action other than agricultural districts will be needed if agriculture is to be preserved.

Persons in other states who seek to learn from New York's experience with agricultural districts need to recognize that there is a plentiful intermingling of farm and nonfarm lands throughout most of New York. Agricultural districts may not be an effective mechanism for encouraging continued agricultural production in more urbanized areas where there is no nearby land available for nonfarm uses. Experience with zoning in most parts of the United States suggests, however, that a non-authoritarian approach to land use guidance is more likely to be acceptable by farm people than an exercise of police power.

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# Transferability of Microeconomic Data over Time: An Illustration*

L. L. SAMMET

**Data from a long series of plant cost syntheses are used to illustrate the feasibility of transferring microeconomic data over time. The effect of technical change in building construction practices on index-transferred investment costs is illustrated. A bias in the BLS construction wage rate indices is identified.**

***Key words:*** **microeconomic data; transfer over time.**

DATA TRANSFER over time is a convenience and economy in many applications. In large, complex studies this may also be the key to feasibility for the reason that the numerous component estimates such studies require often cannot be brought to fruition simultaneously. Pursuit of such studies then may hinge on the feasibility of transferring such components to a common point in time.

This is the general context of this paper. The specific question posed is whether cost syntheses that are realistic in terms of current factor price relationships and technology can be developed for specific processing operations using basic data—with appropriate adjustment—from another time period. The data considered are drawn from studies initially focused on intrafirm and industry adjustments with potential for improving efficiency in the packing and shipping of California pears [1].

Cost synthesis was the principal analytical technique used; this required the development, at high cost in research resources, of numerous physical input-output and cost-output relationships. Certain of the relationships were subsequently applied over a 10-year period in a series of similar studies concerning other commodities and in the development of major components of more broadly oriented studies of market structure and performance, interregional competition, and intraregional industry organization. This involved the direct transfer of basic physical input-output data and the transfer of previously estimated cost functions through the application of appropriate price indices.

The longer the period over which such data are transferred, the greater the concern must be as to their present validity. This led in a current re-study of earlier work in this series to some testing of this question with respect to the current applicability of production standards for certain processing plant tasks and the feasibility of adjusting building and equipment replacement cost data by means of U. S. Bureau of Labor Statistics (BLS) price indices. The time span considered extends in some instances over the 22-year period, 1950–1972.

As in the original evaluation of such data, answers to the question of transferability cannot be buttressed with statistical tests of validity. Satisfactory statistical tests, for example, are not available for application to production standards data, to engineering estimates of construction costs or of equipment installation and operating costs.[1] Thus, various means peculiar to a given problem may have to be employed to test the realism of transferring input- and cost-output relationships over time. This may involve the use of multiple routes in the estimation of a given relationship, comparison of syntheses with real situations or testing them against expert opinion, constructing indices specific to a given situation, or use of simulation to test the stability of analytical results.

The intensity of such examinations and the feasibility of data transfer will depend on the objectives of the particular study. For example, in the initial studies referred to above, a major objective was the selection of optimum technique, which required reliable production standards data at the level of individual plant tasks. In broader applications—for example, obtaining a good approximation of cost levels and econo-

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[1] Even in engineering estimates based on laboratory test data of high reliability, unmeasured variability usually is associated with specified operating conditions (e.g., ambient temperatures for a cold storage plant and physical operating efficiency of associated compressors and motors).

mies of scale—increased variability might be tolerated in standards related to microelements of the original synthesis, provided no systematic bias had developed over time. Or use of a transfer index at the level of the total cost function rather than complete resynthesis might be satisfactory as well as economical.

## Production Standards

Production standards for labor may be especially susceptible to variation over time. This may stem from a shift in cultural factors that affect worker motivation and achieved rates of output. Similarly, changes in union regulations affecting acceptable production rates, local building or health codes, or technical changes in production processes may limit the transferability of available production standards.[2]

In this illustration the "verification" of previously estimated production standards for labor was attempted through brief surveys in six pear packing plants in 1972 in which plant processes and work methods were observed and a count made of the number of individual workers assigned to specific tasks. No major changes in production processes were found in comparing current and previous observations. Four of the six plants in the survey were observed at times of peak operating rates for the 1972 season, while operations in two plants were observed near the end of the season when daily volume was diminishing but crew size had not yet been adjusted to current volume. In all cases estimates were also obtained from plant managers as to the output rates (receiving and dumping incoming fruit and packaging of cannery and fresh-market fruit) of which the plant would be capable if the available crew were fully utilized. These estimates of "capacity" output rates were then used in conjunction with corresponding production standards from previous studies of specific jobs to estimate the number of workers required at the specified output rate.

The nature of these data and of the comparisons between estimated and observed crew requirements is illustrated in Table 1. Observed data for each plant are the number of box-supply lines (equal to the number of separate crews), the output rate per line hour (based on the plant manager's estimate of product flow rates, columns 2 and 3), and the observed number of workers (last column). Comparison of the number of workers actually observed in the plant survey with estimates based on the production standard for the box-supply operation shows in this instance an exact correspondence between the synthesized work crew and that actually observed.

A summary of data for all jobs observed in the six plants surveyed is given in Table 2. Here the

[2] Production standards, frequently expressed in terms of the "capacity rate" of output obtainable with a single unit rate of input, are the basis in cost synthesis for specifying physical quantities of labor, equipment, and other inputs required in relation to specified rates of output. See French *et al.* [1] for a more complete explanation.

Table 1. Estimation of crew requirements and observed number of workers in the box-supply operation in a sample of pear packinghouses, Lake County, California, 1972

| | | | Estimate of crew required | | | |
|---|---|---|---|---|---|---|
| Plant | Number of lines | Output per line hour[a] | Output per line divided by standard[b] | Number of workers per line[c] | Total number of workers[d] | Observed number of workers |
| A | 1 | 373 | 0.5 | 1 | 1 | 1 |
| B | 2 | 350 | 0.4 | 1 | 2 | 2 |
| C | 1 | 552 | 0.7 | 1 | 1 | 1 |
| D | 1 | 127 | 0.2 | 1 | 1 | 1 |
| E[e] | | | | | | |
| F | 1 | 204 | 0.2 | 1 | 1 | 1 |

[a] Total plant output rate in standard boxes divided by number of supply lines.
[b] Production standard (1950 origin) equals 820 boxes per worker hour (includes allowance for scheduled rest periods and unavoidable delay).
[c] Output in boxes per line divided by production standard and rounded up to the next whole number.
[d] Estimated workers per line multiplied by number of lines.
[e] Box-supply job not performed in this plant.

Table 2. Estimation of crew requirements and observed number of workers in selected job categories in a sample of pear packinghouses, Lake County, California, 1972

| Job | Plant A | Plant B | Plant C | Plant D | Plant E | Plant F |
|---|---|---|---|---|---|---|
| | number of workers[a] | | | | | |
| Dumping[b] | 4 | 6 | 4 | 2 | 1 | 2 |
| | (4) | (6) | (4) | (2) | (1) | (2) |
| Sorting[c] | 70 | 60 | 55 | 18 | 11 | 22 |
| | (70) | (59) | (48) | (13) | (6) | (20) |
| Packing standard box[c] | 29 | 54 | 43 | 10 | [d] | 16 |
| | (28) | (55) | (44) | (9) | | (13) |
| Assemble standard box[c] | 1 | 2 | 1 | 1 | [d] | 1 |
| | (2) | (2) | (1) | [e] | | (1) |
| Assemble carton[b] | 5 | 5 | 4 | 2 | 1 | 1 |
| | (7) | (3) | (4) | (2) | (1) | (1) |
| Place pads and liners, standard box[c] | 2 | 4 | 3[e] | 1 | [d] | 1 |
| | (2) | (6) | | (2) | | (1) |
| Container supply, standard box[c] | 1 | 2 | 1 | 1 | [d] | 1 |
| | (2) | (1) | (2) | (1) | | (1) |
| Container supply, carton[b] | 6[e] | 3 | 4 | 2[e] | 2 | 1 |
| | | (5) | (4) | | (1) | (5) |
| Packed fruit clerical, standard box[c] | 3 | 6 | 6 | 3 | [d] | 3 |
| | (4) | (8) | (6) | (4) | | (3) |
| Packed fruit clerical, carton[b] | 3 | 3 | 2 | 1 | 2 | 1 |
| | (3) | (3) | (5) | (2) | (1) | (2) |
| Lid standard box[c] | 1 | 2 | 1 | 1 | [d] | 1 |
| | (1) | (2) | (1) | (1) | | (1) |
| Setoff standard box[c] | 2 | 1 | 2 | 1 | [d] | 1 |
| | (4) | (6) | (5) | (2) | | (3) |
| Setoff carton[b] | 3 | 2 | 2 | 2 | 2 | 1 |
| | (8) | (6) | (9) | (2) | (2) | (4) |
| Cannery and cull packaging[b] | 4 | 4 | 5 | 2 | 1 | 2 |
| | (4) | (4) | (2) | (1) | (1) | (2) |
| In-plant transportation[c] | 15 | 16 | 15 | 5 | 3 | 6 |
| | (15) | (16) | (9) | (6) | (2) | (8) |
| Total plant | 143 | 170 | 145 | 49 | 23 | 60 |
| | (154) | (182) | (144) | (47) | (15) | (67) |
| Difference as percent of estimated total workers | +7.7 | +7.1 | −0.7 | −4.1 | −34.8 | +11.7 |

[a] Parentheses indicate actual number of workers observed during plant visit. Other entries represent estimated number of workers required = (output rate per hour) ÷ (production standard), rounded to next higher whole number.
[b] Standard developed in 1959.
[c] Standard developed in 1950.
[d] This job was not performed in this plant (it was equipped for packing only cartons—no standard boxes).
[e] This job was not observed in plant survey.

bracketed numbers entered for a given job and plant represent the number of workers actually observed, and the unbracketed numbers represent the estimated number of workers required based on the specified output rate in a given job and plant and the applicable production standard.

The data in Table 2 should be evaluated with two underlying factors in mind. First, the production standards by definition represent capacity output rate under efficient operating conditions.[3] This means that synthesized crew requirements in a given task will tend to fall below the number of workers actually assigned. Second, the volume data used represent approximations to which considerable variance might be attached, particularly as total product flow is converted to subproduct or materials-supply flows.

With these qualifications in mind, observe in Table 2 that, over all job categories and plants, there are notable instances of close correspon-

[3] Observed crew organization may reflect inefficiency in the operation of a particular plant or a planned overstaffing in some jobs to provide a reserve against unforeseen developments, such as unexpectedly large deliveries of raw products.

dence (e.g., the dumping and packing standard-box jobs) and of poor correspondence (e.g., the setoff job). Of the total of 79 complete pairs of data in the table, the synthesized number of workers was equal to or less than the observed number in 63 instances; in only 16 cases was the reverse true. This is a bias consistent with the nature of the production standards and estimating procedure. The difference between the synthesized and observed total number of workers on all jobs in the six plants ranged from 1 to 35 percent. The major discrepancy—in plant E—is in the single job category of sorting.[4] In terms of the total work force in the six plants, the synthesized crews totaled 590 workers compared with a total of 609 actually observed

The results reflect a useful consistency with respect to total plant labor requirements and justify the conclusion that, where method of job performance has not changed, production standards previously estimated in this series of studies are currently applicable.[5] With appropriate adjustment or substitution where indicated in the resurvey, their use should yield estimates of crew organization in relation to output rate that realistically reflect efficient operation under current conditions.[6]

## Cost Function Adjustment through Use of Selected Price Indices

If previously developed production standards for labor and equipment remain applicable and there has been no significant change in process, the original cost synthesis can be updated merely by substitution of current prices. However, the collection of price information and the detailed computations of a complete synthesis generally will be costly.

An alternative is to update previously estimated cost relationships through the use of published price indices. This procedure is examined in the following comparison of index-adjusted and directly priced estimates of the investment costs for buildings required to house the packing operations. By inference the findings are extended to estimates of cost relationships for equipment and other factors.

The building cost functions initially were derived from engineering estimates of the quantities of construction materials and labor required. These quantities were converted to costs in the base year (1950) by the application of appropriate prices. For application in studies made in 1957 and 1972, the costs were similarly recomputed using the same (1950) physical quantities but using current prices in each of the later periods. In intervening years these costs were, in still other studies, adjusted to price levels specific to the particular period through the use of BLS wholesale price indices (WPI).

Such adjustments of estimated investment levels become increasingly suspect as the time span increases because of the increasing likelihood that: (1) technical changes in the building materials and construction industry, along with changes in relative prices of building materials and on-site labor, may lead to substitution in construction materials and methods (i.e., to a change in the "production function" for building construction and substitution within a given production function based on changing price ratios); and (2) bias in the computation of the BLS indices may cause them to reflect incorrectly the actual price movements.

The physical model for these comparisons involves a type of structure commonly used in warehousing and processing plant operations.[7] The computational base consists of the quantities of materials and labor required for the major components of construction in such a building providing 39,200 square feet of floor space. These components, as estimated in 1950, are set out in Table 3 and, along with 1950 prices, provide for the estimates of a 1950 "value base" given in column 5 of the table. These values are the basis for computing over time a construction cost index for the type of building described. Table 3 also gives for 1950, 1957, and 1972 the

[4] The relatively small number of sorters observed in plant E may reflect a difference in sorting requirements, this being an on-ranch packing plant with possibly stricter fruit quality standards in the picking operations than are maintained in large plants serving many growers.

[5] In a notable exception, the setoff job for packed boxes and cartons, estimated values tend to be substantially lower than observed values. The observed high proportion of idle time noted in this job in the plant survey and comments of plant managers suggest that the increased attention to inventory record keeping and the use of this job as the source of reserve labor partially explain the discrepancy in this particular category. (In plant syntheses using these data, a reserve labor supply was provided in a category, "utility labor.")

[6] Production-standard transferability is more readily established if the job is machine rather than hand paced, that is, where operating rate and number of machines and attendants in relation to a given product-flow rate are determined by technical characteristics of the machine rather than performance rate of the attendant. Of the jobs reported in Table 2, only the dumping job is machine paced.

[7] For construction details, see Table 3 footnotes.

Table 3. Construction cost index: physical model, BLS price indices, and price ratios for materials and labor, 1950, 1957, and 1972

| Composition of model[a] | | | Value weights and unit prices, 1950 | | BLS price indices 1950 = 100[c] | | | Price ratios based on direct quotations, northern California[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Component | Units | Quantity | Price per unit[b] | Value weights | 1950 | 1957 | 1972 | 1950 | 1957 | 1972 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| | | | dollars | 1,000 dollars | | | | dollars | | |
| *Materials* | | | | | | | | | | |
| Concrete | cubic yards | 1,952.0 | 10.4 | 20.3 | 100 | 135.9 | 185.7 | 100 | 133.3 | 189.0 |
| Lumber | | | | | | | | | | |
| Structural | 1,000 board feet | 39.9 | 120.0 | 4.8 | 100 | 104.9 | 177.2 | 100 | 114.9 | 223.8 |
| Common | 1,000 board feet | 119.4 | 93.1 | 11.1 | | | | | | |
| Nails | 100 pounds | 30.0 | 10.4 | 0.3 | 100 | 153.5 | 187.6 | 100 | 130.8 | 166.7 |
| Miscellaneous iron | 100 pounds | 43.0 | 20.8 | 0.9 | 100 | 155.1 | 238.0 | 100 | 157.5 | 205.0 |
| Roofing | rolls | 542.0 | 2.55 | 1.4 | 100 | 119.5 | 178.4 | 100 | 154.9 | 196.9 |
| Gravel | cubic yards | 1,220.0 | 3.12 | 3.8 | 100 | 125.3 | 122.5 | 100 | 96.7 | 197.7 |
| Reinforcing steel | 1,000 pounds | 46.2 | 62.4 | 2.9 | 100 | 158.9 | 179.4 | 100 | 158.3 | 175.0 |
| Subtotal | | | | 45.5 | | | | | | |
| *Labor*[e] | | | | | | | | | | |
| *Base rate*[f] | | | | | | | | | | |
| Skilled | hours | 5,821 | 2.19 | 12.8 | 100 | 139.1 | 301.0 | 100 | 148.4 | 353.8 |
| Helper | hours | 1,108 | 1.45 | 1.6 | 100 | 148.5 | 338.1 | 100 | 172.4 | 391.7 |
| Subtotal | | | | 14.4 | | | | | | |
| *Base and "fringe"*[g] | | | | | | | | | | |
| Skilled | hours | 5,821 | 2.34 | 13.6 | | | | 100 | 145.7 | 470.0 |
| Helper | hours | 1,108 | 1.56 | 1.7 | | | | 100 | 168.5 | 558.3 |
| Subtotal | | | | 15.3 | | | | | | |

[a] Building (1950 design) involves 39,200 square feet of roofed floor space and 20,500 square feet of exterior paved storage area; interior, partitioned space for offices; heating, plumbing, and lighting for office and personnel (process equipment not included). Floor, 6" concrete at ground level, wire-mesh reinforced; walls, 8" thick, steel reinforced —½" rods on 8" center—cast-in-place; roof, wood truss, 75-foot span, 20 feet spacing; roof deck, 1" thick boards; and roof covering, 4-ply built-up asphalt. The materials and labor quantities given represent 91 percent of total building costs. The minor components omitted for convenience would not have an appreciable effect on the index computation.

[b] Modal values in "spot" prices observed in northern California in 1950.

[c] From U. S. Bureau of Labor Statistics, wholesale price indices for the years indicated adjusted to 1950 = 100; 1972 indices are averages of data for the first six months only.

[d] Computed from modal values of spot prices observed in northern California with 1950 = 100.

[e] Price ratios for skilled labor are based on weighted average hourly wage rates for the major skilled trades involved—carpenter, cement finisher, roofer, and steelworker (reinforcement). The weights used are the estimated hours of labor required in constructing the model building. The BLS price index for skilled labor is that reported in the category "journeyman."

[f] Indices and price ratios computed on base wage rate only exclusive of payroll taxes and fringe benefits. BLS indices taken from [2]. (1972 indices estimated by extending published 1971 index at average annual increase since 1961 of 6.3 percent; see [2, pp. 4 and 5] for data on average annual increase.) Observed wage ratios based on published union wage scales in building trades for Sacramento, California, and environs.

[g] Data on base plus "fringes" represent ratios based on published hourly base wage rate plus payroll taxes for social security and unemployment benefits; insurance costs for legally mandated workmen's compensation plans; and fringe benefits covering vacation, health and welfare, pension, and miscellaneous benefits.

BLS price indices for each component and local price ratios computed from prices observed through direct sampling in northern California.

The results of four different procedures for estimating the construction cost index in 1950, 1957, and 1972 are given in Table 4. The upper left section of the table gives index numbers separately for materials and labor costs and for total construction costs that were obtained by moving the base year (1950) value weights for

Table 4. Construction cost index with alternative formulations

| Item | 1950 construction model[a] | | | | | | Revised construction model, 1972[b] |
|---|---|---|---|---|---|---|---|
| | 1950 value weights adjusted by BLS index | | | Index derived from value weights computed by application of current prices | | | |
| | 1950 | 1957 | 1972 | 1950 | 1957 | 1972 | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Index computed on base wage rate | | | | | | | |
| Materials | 100 | 125.7 | 177.6 | 100 | 123.9 | 193.0 | 171.4 |
| Labor | 100 | 140.3 | 314.6 | 100 | 151.7 | 363.9 | 335.3 |
| Total | 100 | 129.2 | 210.5 | 100 | 130.6 | 233.9 | 212.7 |
| Index computed on base wage rate plus payroll taxes, insurance, and fringe benefits | | | | | | | |
| Materials | | | | 100 | 123.9 | 193.0 | 171.4 |
| Labor | | | | 100 | 149.7 | 494.8 | 473.2 |
| Total | | | | 100 | 130.4 | 268.9 | 247.3 |

[a] Computed from value weights, indices, and price ratios given in Table 3.

[b] Derived from price data and price ratios in Table 3 and the following data as to physical quantities of materials and labor required: concrete, 1,559 cubic yards; lumber, structural grade, 43,100 board feet, and common, 49,400 board feet; 5/8" plywood, 40,900 square feet; nails, 1,740 pounds; miscellaneous iron, 6,680 pounds; asphalt roofing, 545 rolls; gravel, 1,108 cubic yards; reinforcing steel, 31,200 pounds; and labor, skilled, 5,909 hours, and helper, 473 hours.

the respective elements of construction through application of the appropriate WPI (adjusted to the 1950 base), summing the adjusted value weights, and relating the adjusted total value weight to the corresponding base value. The middle sections (both upper and lower, columns 5, 6, and 7) present the results of similar calculations but with actual materials prices and base wage rates observed in northern California substituted for the nationally computed WPI's. The final column of Table 4 presents computations based on a redesign of the original physical construction model to reflect changes since 1950 in construction practices.

Among the alternative formulations of the cost indices given in Table 4, there is a very close correspondence in the index numbers for 1957. However, significant differences appear in the indices for 1972. For example, using basic labor wage rates, the index computed from the BLS price series (210.5) is approximately 10 percent lower than that computed from observed basic wage rates (233.9). When the construction wage component of the index is computed with observed wage rates, inclusive of payroll taxes and fringe benefits, the index derived from the BLS wage rate series is lower by 20 percent. In terms of the construction wage costs only (excluding materials costs), the BLS wage series yields an index for the labor component 37 percent below that derived from the observed full-cost construction wage [100 (494.8 — 314.6)/494.8 = 37]. Comparison of the 1972 adjusted construction costs, using the 1950 engineering design with costs based on the revised 1972 design, results in a downward adjustment of the index of total cost by about 7 percent.[8]

Several possible explanations for this variation in outcomes are easily identified. The WPI's used, for example, represent national average values, whereas the direct price data used were obtained from spot surveys in northern California. Differences in sampling technique and real differences in regional versus national average price data could account for substantial differences between the nationally computed price series and ratios computed from local spot prices.[9] The WPI national indices of basic construction labor wage rates are lower than the observed wage ratios; this reflects, in part, regional differences as compared with the national

[8] The price indices in columns 2–7 of Table 4 represent Laspeyres (fixed weight) indices. The indices in column 8 represent Paasche (variable weight) indices.

[9] For the most part the correspondence between the price series and locally computed price ratios is close. Exceptional elements (in 1972) include lumber (the price situation was unstable in 1972 when governmental price restraint was being introduced in a time of sharply rising demand); gravel, which is especially susceptible to local market conditions; and miscellaneous iron.

average. (For example, the base rate for journeymen in northern California in 1950 was 95 percent of the national average; in 1957 the corresponding figure was 99 percent; and in 1972 it was 103 percent—a shift that would account for a larger relative movement in ratios based on observed regional wage rates than in the national average BLS indices.)[10]

A second major source of variation in the computed indices of construction is additional payroll costs incurred for construction labor above the basic rate. These additional costs involve payroll taxes for social security and unemployment benefits, insurance costs under legally mandated workmen's compensation plans, and negotiated fringe benefits. They represent direct costs to builders and are reflected in actual levels of construction costs experienced. The fringe benefit costs were a minor factor prior to the early 1960's but have increased rapidly since then.

Since these additional payroll expenses are not taken into account in the computation of the BLS indices of construction labor, they are a source of substantial difference when compared with ratios based on total hourly costs to contractors for construction labor. Thus, for skilled crafts (journeymen), the BLS index for 1972 (1950 = 100) is 301.0, while the ratio of observed total hourly payroll costs in this category is 470.0. The similar comparison for the "helper" category is 338.1 versus 558.3 (Table 3). Adjustment of the building cost index over time, using the BLS indices for building trades, would thus seriously underestimate real changes in the level of current construction costs. However, this problem in regard to the wage index for the building trades could easily be disposed of by constructing an index, weighted according to the quantities of different types of labor involved in the original value base and using wage rate plus fringe benefit cost data in the base and current years readily available in the wage contracts.

An additional source of bias in the use of index numbers as "deflators" over long time periods is the possibility of technical substitution based on the availability of new technique, changes in relative factor prices, or a combination of both effects. This kind of outcome, without sorting out the separate effects of technical change and changes in relative prices, is illustrated in the last column of Table 4. This column presents indices for 1972 that take account of changes in construction practices employed in 1972 as compared with those used in 1950. The new practices achieved growing acceptance in the 1960's and involved primarily the substitution of "tip up" for "cast in place" wall construction, the substitution of plywood for boards in roof-deck construction, and the use of thinner sections and wider spacing of steel reinforcement in concrete wall construction.[11] The 7 percent reduction indicated above in the construction cost index resulting from these new practices is an approximation of long-term substitution effects that would not be accounted for in an adjustment involving only the application of price series data to the original model.

## Conclusions

The following conclusions may be drawn as to the transferability of the types of data involved in the above illustrations.

1. Where there has been no significant change in job requirements, physical input-output data may be applicable over an extended time period. In particular "reuses," their validity may be examined by relatively simple and economical measures. The data obsolescence rate cannot be predicted.
2. In regard to estimates of the investment cost in buildings, the use of price index data to adjust such estimates to a later time period may give consistent results if (a) there are no significant changes in construction practices, (b) allowance is made for variations in regional as compared with national price movements, and (c) the index data are not biased with respect to price to the "consumer."

   With respect to building construction labor, the analysis shows that nationally published indices are "biased" with respect to their reflection of changes over time in costs to users of construction labor as compared with direct payments to workers. The "bias" arises from omission of fringe benefits and other payroll costs from the BLS computation of construction labor wage indices. The extent of the bias, which is progressively growing, is sufficient to in-

10 These ratios were computed from the base wage rates given in U. S. Bureau of Labor Statistics [2].

11 The use of thinner wall sections and wider spacing of steel reinforcement might constitute "cutting corners" rather than a technical substitution if such changes were specific to a particular structure. However, a shift in general design practice as in the present instance may correctly be considered a technical substitution.

validate the BLS wage indices as "movers" in cost relationships involving construction labor and may, in fact, seriously compromise their validity as indicators in more general policy-oriented appraisals of wage rate movements. An easily developed alternative to the BLS index would be the construction of a special index based on readily available contract wage data.

3. By extrapolation of the above analysis, difficulties in the adjustment of cost functions for processing equipment appear likely to be less than for buildings. Prices for important elements of such equipment —e.g., motors, drives, belting, rollers, steel framing, etc.—are established in a national market; and so regional prices for such materials should move in close relation to national price movements and with the nationally computed indices. With respect to equipment-manufacturing labor, fringe benefit costs, payroll taxes, and other nonwage payroll expenses would be paid by the manufacturer and would become part of product price and so be reflected in the price indices. Thus, a major source of difficulty encountered in the use of price index data to adjust building investment costs over time would not apply in regard to process equipment.

The above illustration suggests an extended "shelf life" for some types of microeconomic data. However, on *a priori* grounds and in terms of specific findings reported here, such extension requires careful reexamination of the original data along with appropriate adjustments or substitutions. The data review in some circumstances may be accomplished with relatively inexpensive procedures and will be facilitated if commonly used economic indicators can be maintained over time with minimal bias.

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# Marginal Risk Constraint Linear Program for Activity Analysis*

JOYCE T. CHEN AND C. B. BAKER

**A dichotomous Marginal Risk Constraint (MRC) criterion is proposed to take explicit account of activity income covariance relationships and to restrict the choice of activities within the range of rational combinations. A parametric LP solution procedure is also presented. The E,V boundary approximated is satisfactorily close to that generated from QP.**

***Key words:*** **marginal risk constraint; solution procedure; E,V boundary.**

ALTHOUGH the Mean-Variability (*E,V*) criterion, and thus quadratic programming (QP), is theoretically appealing, it is more difficult to handle computationally than is deterministic linear programming (LP). At the present stage in the art of computation, the computer code for QP models is also much more restrictive in size than are codes available for LP models. These facts place a premium on developing alternative linear models to approximate efficient *E,V* farm plans. Efficiency of the alternative model can be measured by departure of the approximate *E,V* boundary from the boundary generated by QP.

Hazell has proposed a model which minimizes total absolute deviations and which, he claims, retains the good properties of QP models while allowing use of the LP code [2, 6, 11]. Thomas *et al.* have used separable programming to approximate the nonlinear total variance constraint when the mean return is maximized [4, 10].

In this article a Marginal Risk Constraint (MRC) criterion is proposed. This criterion can be fitted into a linear model with dichotomous marginal risk constraints, along with the usual resource restrictions. A multi-stage LP algorithm is proposed to approximate the *E,V* boundary.

## The Marginal Risk Constraint Criterion

### Assumptions

The return from a set of farm enterprise combinations is assumed to be randomly distributed with known finite mean and variance. Further, it is assumed that the investor maximizes his expected return, provided that the marginal "contribution" of each used $x_j$ to the total variance of return does not exceed its expected unit income, divided by a risk aversion parameter, $\alpha$.

### Economic logic and implications of the new constraint

Given the total variance of return, $x'Wx$, the marginal contribution of each $x_j$ to the total variance is $2\sum_{k=1}^{n} S_{jk}x_k$, a linear function of $x_j$, where $S_{jk}$ is the estimated covariance between the returns from activities $x_j$ and $x_k$. This value obviously increases when $x_j$ increases.[1] However, the expected unit income, $\bar{c}_j$, is often assumed to be constant over a specified range. Thus a farmer's risk aversion behavior may be expressed in terms of a marginal risk constraint. Such a constraint restricts the activity's marginal contribution to risk to within a certain functional value of the activity's expected unit income. The MRC is imposed for each activated activity.

The idea underlying this criterion was originally derived from the fact that if $x_j$ is in the optimal plan, it should not be activated beyond the point where the marginal expected utility of $x_j$ is zero. Let the expected utility function to be maximized be given as

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[1] Since

$$\left(\frac{\partial x'Wx}{\partial x_j}\bigg| x_1, x_2, \ldots, x_{j-1}, x_{j+1}, \ldots, x_n\right)$$
$$= 2S_j^2 x_j + 2\sum_{k \neq j} S_{jk} x_k$$
$$= 2S_j^2 x_j + K,$$

the marginal contribution of $x_j$ to the total variance increases when $x_j$ increases, where $K$ is a constant.

$$E(u) = \bar{c}'x + \frac{\alpha}{2} x'Wx.$$

If $x_j^o \neq 0$, then $\left[\dfrac{\partial E(u)}{\partial x_j}\right]^o = \bar{c}_j - \alpha \sum_{K=1}^{n} S_{jk}x_k \geqslant 0$.[2] Thus no single activity can be activated beyond the level at which its marginal expected utility is zero.[3]

Analogous to the production response models, the ridge-lines of iso-utility curves mark the boundary between rational and irrational combinations of enterprises. Since the MRC restricts the choice of each used $x_j$ to be within the range of non-negative marginal utility, this new criterion actually restricts the choice of activities to be within the range of rational combinations.

The effect on total income variance of covariance relationships between the marginal returns of individual activities is obvious and significant [9]. Heady [7] has stated that covariance relationships are fundamental in comparing farm enterprises as a means of hedging against uncertainty. The proposed MRC model provides an efficient means for doing so.

## Properties of the new constraints

It will be convenient to develop and explore the properties of the MRC program with a simple example problem in two variables. Consider the following QP model:

*Model 1:*

Maximize

$$f(x) = (4\ \ 3.5)\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} - \frac{\alpha}{2}(x_1\, x_2)$$

$$\begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} (\text{for } \alpha = +\infty \text{ to } 0),$$

subject to

(1) & (2)

$$\begin{bmatrix} 4 & 1 \\ 4 & 3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \leqslant \begin{bmatrix} 8 \\ 12 \end{bmatrix}.$$

and (3)

$$x_1, x_2 \geqslant 0.$$

The center of the ellipse, $f(x) =$ constant, can be calculated by the following arithmetic:

$$\frac{\partial f(x)}{\partial x_1} = \frac{\partial f(x)}{\partial x_2} = 0,$$

which implies $(x_1, x_2) = \left(\dfrac{3}{4\alpha}, \dfrac{1}{2\alpha}\right)$. As is shown in Figure 1, the center moves from the origin to the boundary of the domain along the path of $OPP'$, a straight line with a slope of $x_1/x_2 = 3/2$. When $\alpha$ decreases, the optimal point moves from the origin to the boundary point $A$. After reaching $A$, the optimal point changes in its direction of movement toward the point $B$ and then changes toward and arrives at the point $D$, where point $D$ is a conventional LP solution. Solutions at critical turning points of Model 1 correspond to points $A$, $B$, and $D$ in Figure 1.

The MRC criterion suggests that the linear part of the objective function shall be maximized subject to the original resource constraints (1) and (2), and the following marginal risk constraints,

$$\begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \leqslant \frac{1}{\alpha}\begin{bmatrix} 4 \\ 3.5 \end{bmatrix}, \text{ if } x_1, x_2 \neq 0.$$

Note the above "if" constraints which indicate that a straight LP is not applicable. However, if there is a simple-to-find improvement on a LP solution, then it would serve as a good starting point from which to derive a better solution. An initial LP model for this example problem was therefore specified as follows:

*Model 2:*

Maximize

$$g(x) = (4\ \ 3.5)\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

subject to

(4) & (5)

$$\begin{bmatrix} 4 & 2 \\ 2 & 4 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \leqslant \frac{1}{\alpha}\begin{bmatrix} 4 \\ 3.5 \end{bmatrix},$$

$$\left(\text{for } \frac{1}{\alpha} = 0 \text{ to } +\infty\right)$$

[2] The restriction naturally implies that if $x_j^o = 0$, then the sign of $\left[\dfrac{\partial E(u)}{\partial x_j}\right]^o$ is unrestricted. According to the Kuhn-Tucker optimality conditions for a saddle value problem [8], the marginal expected utility of any unused activity evaluated at the solution point can be of any sign and thus should *not* be restricted.

[3] This statement holds irrespective of the sign of each $a_{ij}$ in the model. However, if the output from $x_j$ is an intermediate product, used as an input for final goods production, then the market value of the intermediate product can be used to specify and constrain the marginal expected utility from such an activity. That is, instead of restricting $(0 - \alpha W_j x^o)$ to be non-negative, one should restrict $(c^*_j - \alpha W_j x^o)$ to be non-negative, where $c^*_j$ is the estimated market value of this intermediate product and $W_j$ is the $j$th row of $W$ matrix.

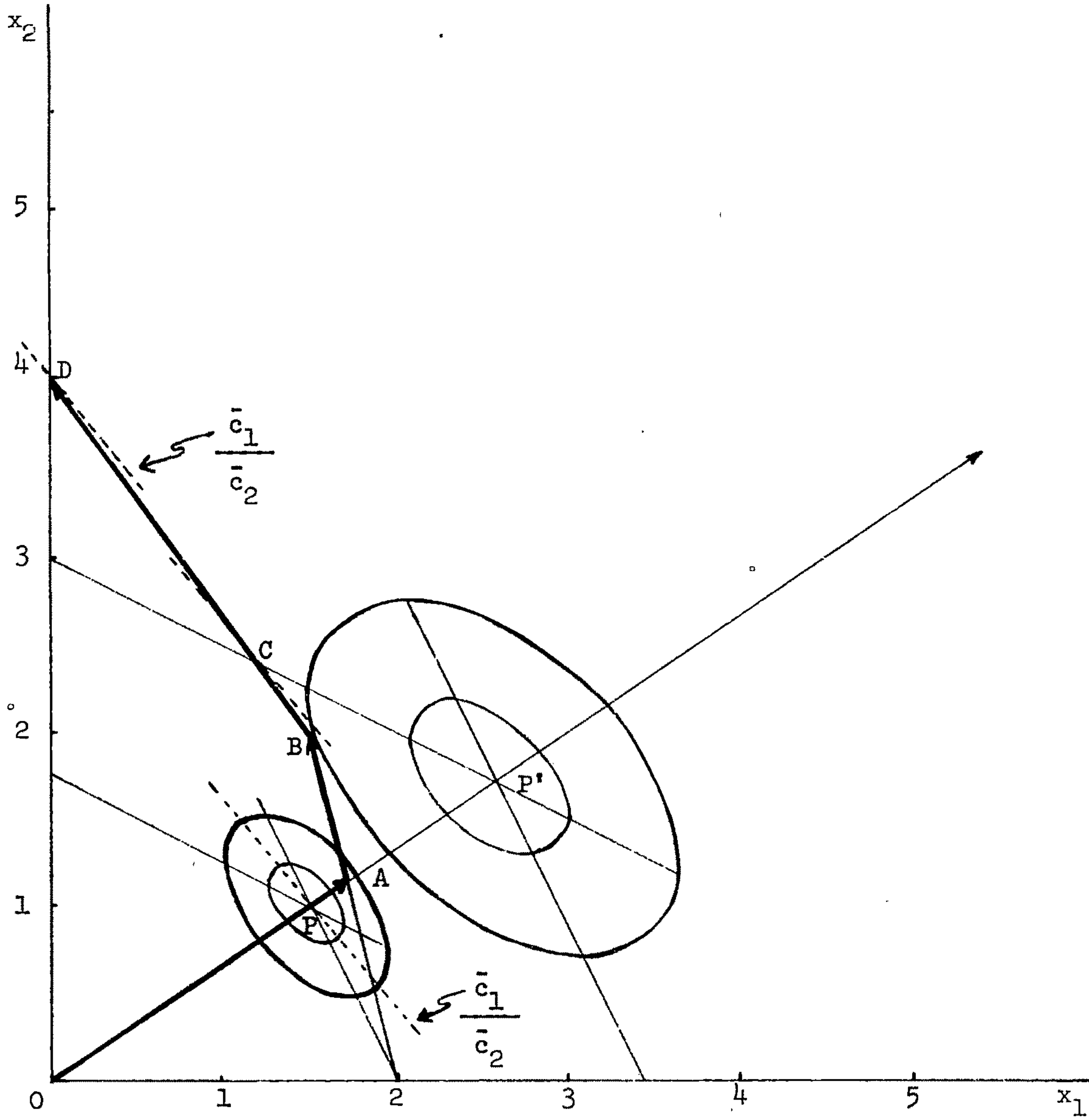


**Figure 1. Solution path of QP and MRC models**

and

the restraint equations (1), (2), and (3) (See Model 1).

The restraint equations (4) and (5) are derived from the quadratic objective function, $f(x)$. Thus the MRC with respect to $x_1$ and $x_2$ must be satisfied in Model 2, no matter whether $x_1$ and $x_2$ are used in the solution.

The solution of Model 2 can be easily improved. If the dual solution with respect to the MRC of an unused activity assumes a zero value, the restriction that *must be satisfied* actually has not affected the solution. Otherwise, if it assumes a positive value, removing this MRC and the associated unused activity can certainly improve the solution objective value and thus lead to a better solution.[4]

Solutions obtained at basis changes of Model 2 correspond to points *A*, *B*, and *D* in Figure 1. Except in the point D, which is the conventional LP solution, both $x_1$ and $x_2$ are activated and thus no further improvement is needed. When

[4] The covariance matrix, *W*, being positive semidefinite, has ensured the improved solution based on Model 2 of not being far from the optimum of the dichotomous MRC linear program which, in fact, is an integer program.

$1/\alpha$ increases, the boundary of the MRC is moved further from the origin, as shown in Figure 1. Correspondingly, solutions approximated by the MRC criterion also move along $OABD$ for the example two variable problem.

The MRC has therefore effectively restricted the decisions according to the assumed $E,V$ risk aversion behavior. The MRC thus can be used to modify the conventional LP code for decision making under risk. A multi-stage LP algorithm based on Model 2 specification will be presented and its associated mathematical logic discussed.

## A Marginal Risk Constraint Linear Program (MRCLP)

The Marginal Risk Constraint Linear Program (MRCLP) involves the new marginal risk constraint criterion as well as an associated multi-stage LP algorithm, proposed to approximate the $E,V$ solutions of quadratic programming. Since the risk aversion rate, $\alpha$, is often unknown, it is desirable to approximate the whole $E,V$ boundary for the decision maker. Parametric programming is therefore required.

The multi-stage parametric algorithm proceeds as follows:[5]

(1) Find a set of optimal solutions at changes in the basis of the following parametric LP problem:

Maximize $\bar{c}'x$

Subject to

$$Ax \leqslant b,$$

$$Wx \leqslant \frac{1}{\alpha}\ \bar{c}, \left(\text{for } \frac{1}{\alpha} = 0 \text{ to } + \infty\right)$$

and $x \geqslant 0.$

(2) Terminate the computation and record the whole set of solutions and their corresponding $\bar{c}'x^o$, if none of the dual solutions associated with the MRC of the unused activities assumes a positive value.[6] Otherwise, if an $x_j$ is not activated while its corresponding MRC is restrictive, for all $K$ at which $K \leqslant k^*$, then record only the solutions of the iteration $(k^* + 1)$ and afterwards.[7] Then formulate a new program by removing the $x_j$ vector and its corresponding MRC and go to (3).

(3) Find a new set of solutions at changes in the basis of the new program for which the highest $\bar{c}'x^o$ value is less than the lowest previously recorded linear objective value and return to (2).

Each step eliminates one or more of the relatively risky activities. A set of solutions for higher mean values is generated before a set for lower mean values. The whole set of $E,V$ combinations can be approximated in a certain finite number of computational steps.[8]

The procedure does not allow nor in fact is it necessary to allow for an activity dropped at one step of the computation to enter the basis again at a later step. When the investor becomes more averse to risk, the $\alpha$ value increases and thus the marginal risk generated from each activity has to be more severely restricted. The comparatively risky activity which was previously dropped would certainly not be a useful candidate again. This conclusion also is consistent with the fact that solutions with higher mean values along the $E,V$ boundary are generated before these with lower mean values and that more risky activities are dropped before the less risky activities.

## A Numerical Illustration

To illustrate the multi-stage algorithm as well as the heuristic concept discussed, QP and

[5] If the investor's risk aversion behavior can be well explained by the MRC criterion and the $\alpha$ value is known or can be estimated, then parametric approach is not needed in each step of computation.

[6] Note also that except for the last solution point, obtained with the first step model, which is the conventional LP solution, none of the solution points at which $\rho^o_{m+j} = 0$, for all $j$, should be used. That is because there is only one point along the Markowitz's $E,V$ boundary at which risk is not considered. Thus after step 1 of computation, the solutions in which risk is ignored are not economically meaningful.

[7] Experience has shown that within each stage of computation, if an activity $x_j$ previously not in the solution basis comes in when the risk restriction is relaxed, that is, as $\frac{1}{\alpha}$ becomes larger, then it will stay in the basis at least until $\rho^o_{m+j}$ becomes zero. Thus, if at a certain iteration the situation is that none of the dual variables associated with the MRC of the unused activities assumes a positive value, then it is also true for the solutions thereafter.

[8] If faster convergence is required, a heuristic rule of thumb can be applied to remove several risky activities each time. For example, at a certain stage of computation, let (1) $x^o_{K,n-1} = 0$ and $\rho^o_{K,m+n-1} \neq 0$ for all $K$ at which $K \leqslant k^* - 1$; (2) $x^o_{K,n} = 0$ and $\rho^o_{K,m+n} \neq 0$ for all $K$ at which $K \leqslant k^*$; and (3) in the solutions at iteration $(k^* + 1)$ and thereafter, none of the dual variables associated with the MRC of unused activities assumes a positive value. Then, instead of dropping $x_n$ only in the next step of computation, both $x_{n-1}$ and $x_n$ vectors may be removed simultaneously for approximating the solutions.

**Table 1. The first-stage MRCLP results at change in basis[a]**

| Plan | $x^o_1$ | $x^o_2$ | $x^o_3$ | $x^o_4$ | $x^o_5$ | $\rho^o_{3+1}$ | $\rho^o_{3+2}$ | $\rho^o_{3+3}$ | $\rho^o_{3+4}$ | $\rho^o_{3+5}$ | $E$ | $SD$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 0.63 | | 0.75 | | >0 | | >0 | | | 7.75 | 2.73 |
| 2 | | 25.00 | | 30.00 | | >0 | | =0 | | | 310.00 | 108.74 |
| 3* | | 30.00 | | 30.00 | | =0 | | | | | 330.00 | 116.19 |

[a] Throughout this and following tables in this paper, blank entries denote zeros. =0's in the dual solutions denote that the associated slacks have just come into the solution basis with values of zeros. $E$ denotes the value of $\bar{c}'x^o$. $SD$ denotes the value of $(x^{o\prime}Wx^o)^{1/2}$. Plans identified with * comprise the final MRCLP results.

MRCLP are applied to a simple numerical example at which $n = 5$, $m = 3$. Specifically,

$$c = \begin{bmatrix} 2 \\ 4 \\ 3 \\ 7 \\ 5 \end{bmatrix}, \; W = \begin{bmatrix} 5 & 2 & 1 & 1 & 3 \\ 2 & 5 & 0 & 1 & 2 \\ 1 & 0 & 7 & 4 & 2 \\ 1 & 1 & 4 & 8 & 0 \\ 3 & 2 & 2 & 0 & 5 \end{bmatrix}$$

$$A = \begin{bmatrix} 1 & 0 & 1 & 2 & 1 \\ 0 & 2 & 0.5 & 0 & 1 \\ 0.5 & 1 & 0 & 1 & 0.5 \end{bmatrix}, \text{ and } b = \begin{bmatrix} 60 \\ 60 \\ 60 \end{bmatrix}.$$

Parametric solutions (Table 1) obtained with the first-stage MRCLP show that both $x_1$ and $x_3$ are excluded even in the final solution point which is equivalent to the conventional LP result, while $\rho^o{}_{3+1} > 0$ for Plans 1 and 2, and $\rho^o{}_{3+3} > 0$ for Plan 1. Thus at the second stage of computation, activities $x_1$ and $x_3$ and the associated MRC were dropped. New solutions at basis changes were then obtained and are presented in Table 2 which shows that no third-stage is required for this problem. Plans 1*, 2*, and 3* comprise the final MRCLP results.[9]

Values of $E$ and $SD$, from Plans 1*, 2*, and 3* are on the $E,V$ boundary as approximated by the MRCLP. Points on the approximated boundary between those traced by Plans 1* and 2*, and Plans 2* and 3* can be found by linear interpolations. Since Plans 1*, 2*, and 3* closely resemble the basic solutions obtained with QP (Table 3), the $E,V$ boundary approximated by the MRCLP for this example closely resembles the $E,V$ boundary approximated by QP.[10]

## Concluding Comparisons

When the proposed program is considered as a substitute for QP, an objective comparison between this model and the other linearized models is necessary. The relative efficiency of the alternative linearized models can be measured by the relative departures from the $E,V$ boundary approximated by QP. In a number of examples and in an empirical application with a multiperiod Illinois cash-grain farm growth model, the MRCLP has revealed favorable characteristics [3, Ch. 4]. Solutions obtained with the MRCLP are surprisingly similar to those obtained with QP.

The marginal risk constraint criterion performed well in the experience of the authors, and it is economically meaningful in terms of rational decision making. It is therefore not unreasonable to believe that this criterion can sometimes explain and predict farmers' behavior.

The disadvantage associated with the MRCLP is the number of successive runs of LP required to generate the final results. The number of runs required is often a function of the number of

[9] Because $x_1$ and $x_3$ are not activated in the Plan 3*, the last solution point of the second stage model of this example is also equivalent to the conventional LP result.

[10] QP and MRCLP as well as the Hazell's MOTAD models have been applied to the Hazell's numerical example problem [6, p. 60]. Solutions at basis changes of QP are obtained by using the Rand program [5], and linear interpolations are performed in the results from the MRCLP and MOTAD. The resulting comparisons indicate a surprising similarity among solutions obtained with the MRCLP and the QP models, which differ less than do those from the MOTAD program.

**Table 2. The second-stage MRCLP results at change in basis**

| Plan | $x^o_1$ | $x^o_2$ | $x^o_3$ | $x^o_4$ | $x^o_5$ | $\rho^o_{3+1}$ | $\rho^o_{3+2}$ | $\rho^o_{3+3}$ | $\rho^o_{3+4}$ | $\rho^o_{3-5}$ | $E$ | $SD$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1* | — | 6.44 | — | 19.62 | 20.76 | — | >0 | — | =0 | >0 | 266.92 | 78.93 |
| 2* | — | 14.29 | — | 14.29 | 31.43 | — | >0 | — | | =0 | 314.29 | 98.99 |
| 3 | — | 30.00 | — | 30.00 | | — | =0 | — | | | 330.00 | 116.19 |

Table 3. The quadratic programming results at change in basis

| Plan | $x^0_1$ | $x^0_2$ | $x^0_3$ | $x^0_4$ | $x^0_5$ | $E$ | $SD$ |
|---|---|---|---|---|---|---|---|
| 1 | | 6.44 | | 19.62 | 20.76 | 266.92 | 78.93 |
| 2 | | 19.25 | | 19.25 | 21.51 | 319.25 | 97.61 |
| 3 | | 30.00 | | 30.00 | | 330.00 | 116.19 |

variables which require the dichotomous risk constraint specification. Thus unless a computer code is written to make the successive runs, for large matrices the MRCLP is convenient only for problems in which the number of risky activities is small, relative to the number of total decision variables plus the number of linear constraints. This situation often exists with a multi-period farm firm growth model in which groups of nonstochastic financial activities as well as resource transferring activities have greatly expanded the model's size causing computational difficulties associated with QP.

A special multi-period model formulation is to let the cash row(s) in the matrix reflect all outlays and inflows that occur within or at the end of the modeled period. Introduce transfer vectors that transmit cash surpluses from one season to the next, and one vector that transfers all cash thus accumulated to the objective function.

Sometimes, (e.g. in capital budgeting [1]) it is appropriate to consider the risk associated with the above stated final cash-transferring activity, rather than to consider the risk associated with the income generated from each individual production activity. Then the quadratic entry of this vector constitutes the only entry in the quadratic part of the objective function. As a consequence the MRC for this vector constitutes the only marginal risk constraint needed for the model, and thus only one stage of the LP operation is needed for deriving an approximated $E,V$ boundary. This is an extreme case at which the MRCLP can be most conveniently applied.

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# The Solution of Nonlinear Separable Programs*

A. D. Woodland

**It is shown that separable nonlinear programming problems may be solved approximately by using existing quadratic programming algorithms. The approach is to approximate the gradient functions by segmented linear functions which implies the approximation of the objective function by a smooth series of quadratic functions. A numerical example illustrates the technique.**

***Key words:*** **separable nonlinear programming; approximation.**

Since a large class of economic problems can be formulated and solved as concave programming problems, it is desirable, from a practical point of view, that the solution algorithms be numerically accurate and be efficient in terms of the cost of solution. Generally a trade-off between accuracy and efficiency is available as is evidenced by the widespread use of linear approximation techniques. Typically these permit the approximate solution of a problem by linear programming instead of the accurate solution of the problem by a less efficient nonlinear programming algorithm. To preserve the linear program as an efficient computational device, the procedure has been to approximate each nonlinear term of a separable objective function by a series of connected linear segments. Similarly, separable nonlinear constraints may be approximated by segmented linear functions.[1]

Baumol and Bushnell [1] have investigated the implications of this approximation method for the solution of nonlinear programs. Their general conclusion is that there is little reason to believe that the linear programming solution will closely approximate the true solution. While it seems that their method of approximation (using a *single* linear function to approximate a quadratic function) may be partly to blame for their results, their warning should certainly be kept in mind.

Rather than approximate each term in a separable objective function by a segmented linear function, the approach taken in this paper is to approximate each of the gradients by a segmented linear function. This is equivalent to approximating each term in the objective function by a smooth piece-wise quadratic function and permits the problem to be approximated by a quadratic programming problem if the constraints are linear. The technique is extremely simple though it has not hitherto been used to the knowledge of the author.

There are many problems in economic analysis which can be expressed in terms of a maximization problem with a separable nonlinear objective function and linear constraints. One particular class of such problems of particular interest to agricultural economists is the class of spatial and temporal equilibrium models which have recently been discussed in detail by Takayama and Judge [5]. If these models have linear production and allocation activities and nonlinear demand and supply functions which are not interdependent, then the equilibrium may be obtained from the solution to a maximization problem with a separable nonlinear objective function and linear constraints. The technique developed in this paper is therefore applicable to the solution of such models.

In the next section the technique is developed; the third section provides an alternative but related technique which has more general application; the fourth section provides an illustrative numerical example; and the paper concludes with some general comments.

## Approximation Technique

To emphasize an important area of application, the approximation technique is discussed

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[1] For further details on linear approximation techniques in separable programming, see, for example, Hadley [2, Ch. 4]. It should also be noted that some nonseparable functions may be rewritten as separable functions using a transformation of variable technique.

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in the context of a simple competitive market equilibrium model involving nonlinear product demand functions. Let $f_j(x_j)$ be the inverse demand function for product $j$; $b_i$ be the fixed endowment of resource $i$; $a_{ij}$ be the fixed input of resource $i$ required to produce one unit of product $j$; $w_i$ be the unit price of resource $i$; and let $x_j$ be the quantity of product $j$ produced and sold. There are $M$ products and $N$ resources. Equilibrium in this model requires that price equals unit cost for those products actually produced and that supply equals demand for those resources with positive prices. Conversely, if price exceeds unit cost, then the product is not produced, and if supply exceeds demand for a resource, then its price is zero. Formally, a competitive market equilibrium is defined as a solution $(x, w, v, u)$ to

(1)

$$f_j(x_j) + v_j = \sum_{i=1}^{N} a_{ij}w_i \qquad v_jx_j = 0 \qquad v_j,x_j \geqq 0 \qquad j = 1, \ldots, M$$

$$\sum_{j=1}^{M} a_{ij}x_j + u_i = b_i \qquad u_iw_i = 0 \qquad u_i,w_i \geqq 0 \qquad i = 1, \ldots, N.$$

Throughout the paper the following assumption is made:
*Assumption 1:* The $f_j(x_j)$ are strictly decreasing functions.

In the spirit of Samuelson [3] and Takayama and Judge [4], system (1) may be interpreted as the necessary and sufficient (under Assumption 1) Kuhn-Tucker conditions for the solution of the artificial maximization problem:

(2)
Maximize $$\sum_{j=1}^{M} F_j(x_j)$$

subject to

$$\sum_{j=1}^{M} a_{ij}x_j \leqq b_i \qquad i = 1, \ldots, N$$
$$x_j \geqq 0 \qquad j = 1, \ldots, M$$

where

$$F_j(x_j) \equiv \int_0^{x_j} f_j(\xi_j)d\xi_j \qquad j = 1, \ldots, M.$$

If the inverse demand functions $f_j(x_j)$ were linear, then each $F_j(x_j)$ would be quadratic and (2) would be a quadratic programming problem for which several solution algorithms exist.[2] The purpose of this paper is to show how quadratic programming algorithms may be used to solve (2) approximately when the functions $f_j(x_j)$ are nonlinear. Though cast in terms of a competitive market equilibrium problem, (2) may be thought of as *any* separable programming problem where each term of the objective function is strictly concave and the constraints are linear. The task is to provide an algorithm for the approximate solution of such a problem.

[2] Some of the available algorithms are discussed in Hadley [2].

Suppose each $f_j(x_j)$ is approximated by a continuous segmented function $g_j(x_j)$ which has strictly negative slope throughout its domain. Clearly this approach is equivalent to approximating each $F_j(x_j)$ by a piece-wise quadratic function $G_j(x_j)$ which is continuous and smooth. Instead of solving problem (2), the approach of this paper is to solve the approximating maximization problem obtained by replacing the $F_j(x_j)$ in (2) by the $G_j(x_j)$ functions:

(3)
Maximize $$\sum_{j=1}^{M} G_j(x_j)$$

subject to

$$\sum_{j=1}^{M} a_{ij}x_j \leqq b_i \qquad i = 1, \ldots, N$$
$$x_j \geqq 0 \qquad j = 1, \ldots, M.$$

In general this approximating problem is not a quadratic programming problem since each $G_j(x_j)$ is a piece-wise quadratic function, not a quadratic function. It remains to construct another problem which is a quadratic programming problem and which is equivalent to the approximating problem. Two such approaches are considered, one here and one in the following section.

The approximation technique developed in this section depends upon the following assumption:
*Assumption 2:* The $f_j(x_j)$ are strictly convex functions.

Let the corners of the segmented linear function $g_j(x_j)$ be given by the pairs $(\lambda_{jl}, \mu_{jl})$ such that $\lambda_{jl} = g_j(\mu_{jl})$ for $l = 1, 2, \ldots, L_j$ where $l$ is chosen such that $\lambda_{j1} > \lambda_{j2} > \ldots > \lambda_{jL_j}$ and where $L_j$ is the number of linear segments in $g_j(x_j)$. New linear functions $g_{jl}(x_{jl})$ $(j = 1, \ldots, M;\ l = 1, \ldots, L_j)$ are defined as follows: The intercepts are given by

$$(4) \qquad g_{jl}(o) \equiv g_j(\mu_{jl}) = \lambda_{jl} \qquad l = 1, \ldots, L_j$$

and the slopes $\omega_{jl}$ by

$$1/\omega_{j1} = y_{j1}$$

(5)

$$1/\omega_{jl} = y_{jl} - y_{j,l-1} \qquad l = 2, \ldots, L_j$$

where $y_{jl} \equiv \partial h_j(\theta_j)/\partial\theta_j$ for $\lambda_{j,l+1} < \theta_j < \lambda_{jl}$ and where $h_j(\theta_j)$ is the inverse function of $g_j(x_j)$. The construction of the $g_{jl}$ functions is illustrated in Figure 1. Here $g_j$ is seen as the horizontal summation of the $g_{jl}$ functions whenever they correspond to positive $x_{jl}$.[3] The two assumptions are crucial for this aggregation property since the slope of $g_j$ must decrease as each successive linear function $g_{jl}$ is added to the previous ones.

An important relationship between $g_j$ and the $g_{jl}$ functions is provided by the following lemma.

*Lemma 1:* For any $j$ $(j = 1, \ldots, M)$ and any $x_j \geqq 0$, the following relationship holds:

$$G_j(x_j) = \max\left\{\sum_{l=1}^{L_j} G_{jl}(x_{jl}) : \sum_{l=1}^{L_j} x_{jl} = x_j, \quad x_{jl} \geqq 0 \quad l = 1, \ldots, L_j\right\}$$

where

$$G_{jl}(x_{jl}) \equiv \int_0^{x_{jl}} g_{jl}(\xi_{jl})\,d\xi_{jl} = \lambda_{jl}x_{jl} - 1/2\ \omega_{jl}x_{jl}^2.$$

*Proof:*

It will suffice to consider the example illustrated in Figure 1. Suppose, for example, that $x_j$ is equal to $\overline{OA}$. Then the solution to the problem of the lemma is obviously

$$x_{j1} = \overline{OF},\ x_{j2} = \overline{OE}, \text{ and } x_{j3} = 0$$

[3] Heuristically, one can think of the segmented linear function $g_j$ as the market inverse demand function obtained by horizontally summing the "individual" inverse demand functions $g_{jl}$.

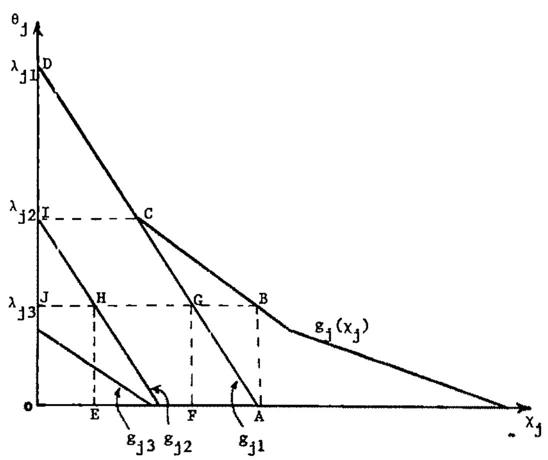


**Figure 1**

where

$$\overline{OF} + \overline{OE} = \overline{OF} + \overline{FA} = \overline{OA}.$$

Now

$$G_{j1}(\overline{OF}) = \text{area } OFGD,$$

$$G_{j2}(\overline{OE}) = \text{area } OEHI = \text{area } FABCG,$$

and

$$G_j(\overline{OA}) = \text{area } OABCD = G_{j1}(\overline{OF}) + G_{j2}(\overline{OE}).$$

Therefore, the optimum value for the objective function is equal to $G_j(\overline{OA})$. For any other values of $x_j$ a similar conclusion holds. This completes the proof.[4]

Now consider the quadratic programming problem defined in terms of the $G_{jl}(x_{jl})$ functions:

(6)
Maximize

$$\sum_{j=1}^{M}\sum_{l=1}^{L_j} G_{jl}(x_{jl})$$

subject to

$$\sum_{j=1}^{M} a_{ij}\sum_{l=1}^{L_j} x_{jl} \leqq b_i \qquad i = 1, \ldots, N$$

$$x_{jl} \geqq 0 \qquad j = 1, \ldots, M \quad l = 1, \ldots, L_j.$$

The following proposition follows immediately from Lemma 1 and contains the main result of this section.

*Proposition 1:*

The solution to the approximate problem (3) may be obtained by solving the quadratic programming problem (6) for the $x_{jl}$ and forming $x_j$ using the relation $x_j = \sum_l x_{jl}$.

*Proof:*

The maximum function value for problem (6) is

$$\underset{x_{jl}}{\text{Max}}\left\{\sum_{j=1}^{M}\sum_{l=1}^{L_j} G_{jl}(x_{jl}) : \sum_{j=1}^{M} a_{ij}\sum_{l=1}^{L_j} x_{jl} \leqq b_i,\ x_{jl} \geqq 0 \text{ all } i, j, l\right\}$$

[4] The statement and proof of this lemma is due to T. Kawaguchi and Y. Maruyama. It provides a simpler and more direct proof for Proposition 1 than that contained in the original draft where the Proposition was proved by showing the equivalence between the Kuhn-Tucker conditions for problems (3) and (6).

$$= \underset{x_j}{\text{Max}}\Big\{\sum_{j=1}^{M} \underset{x_{jl}}{\text{Max}}\Big\{\sum_{l=1}^{L_j} G_{jl}(x_{jl}) : \sum_{l=1}^{L_j} x_{jl} = x_j, x_{jl} \geqq 0 \text{ all } l\Big\} : \sum_{j=1}^{M} a_{ij}x_j \leqq b_i, x_j \geqq 0 \text{ all } i, j\Big\}$$

$$= \underset{x_j}{\text{Max}}\Big\{\sum_{j=1}^{M} G_j(x_j) : \sum_{j=1}^{M} a_{ij}x_j \leqq b_i, x_j \geqq 0 \text{ all } i, j\Big\}$$

by Lemma 1, thus proving the Proposition.

Thus, if each term in a separable objective function can be approximated by a smooth series of quadratic functions, then this proposition shows how a quadratic programming algorithm may be used to provide an approximate solution to the separable programming problem. The cost of using this technique is, of course, the increase in the number of variables; the greater the number of quadratic functions used to approximate the true function, the greater the number of variables and the greater the demands upon computer capacity.

## Alternative Specification

The specification of the linear functions $g_{jl}(x_{jl})$ just discussed requires Assumption 2 to hold. The specification to be briefly discussed in this section does not require Assumption 2 to hold and is therefore more general. On the other hand its demands upon computer capacity are greater.

The alternative specification of the linear functions $g_{jl}(x_{jl})$ is as follows. The intercepts are given by (4) as before while the slopes $\omega_{jl}$ are given by

$$(7) \qquad 1/\omega_{jl} = y_{jl} \qquad l = 1, \ldots, L_j.$$

Further, the domain of each function is restricted by requiring that

$$(8) \quad x_{jl} \leqq k_{jl} \equiv \mu_{j,l+1} - \mu_{jl} \qquad l = 1, \ldots, L_j; \;\; \mu_{j1} \equiv 0.$$

The construction of the $g_{jl}(x_{jl})$ functions is illustrated in Figure 2. Again $g_j(x_j)$ is the horizontal aggregation of the $g_{jl}(x_{jl})$ functions taking into account their restricted domains. Because of the restrictions on the domains, Assumption 2 is not required.

An important relationship between the $g_{jl}(x_{jl})$

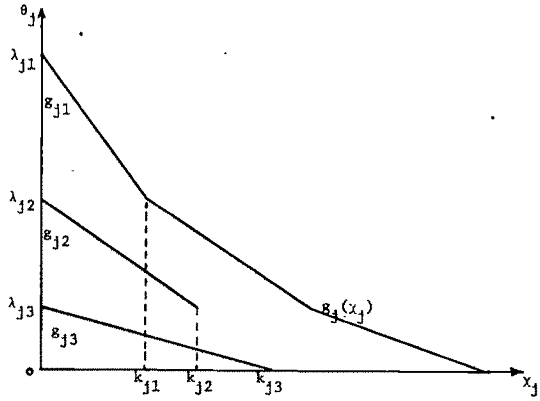


Figure 2

functions and $g_j(x_j)$ is provided by the following lemma.

*Lemma 2:*

For any $j(j = 1, \ldots, M)$ and any $x_j \geqq 0$, the following relationship holds:

$$G_j(x_j) = \text{Max}\{\sum_l G_{jl}(x_{jl}) : \sum_l x_{jl} = x_j, \; k_{jl} \geqq x_{jl} \geqq 0 \; l = 1, \ldots, L_j\}.$$

The proof is very simple and is therefore omitted. The following proposition follows immediately from the Lemma.

*Proposition 2:*

The solution to the approximate problem (3) may be obtained by solving the quadratic programming problem (6), augmented by the constraints $x_{jl} \leqq k_{jl}$ $(j = 1, \ldots, M;\ l = 1, \ldots, L_j)$, for $x_{jl}$ and forming $x_j$ using the relation $x_j = \sum_l x_{jl}$.

This shows how to solve the approximate problem (3) when the gradient functions $g_j(x_j)$ are not convex. This specification of the $g_{jl}(x_{jl})$ function requires just as many variables as the specification discussed in the previous section but, in addition, involves upper-bound constraints on each of the $x_{jl}$ variables.

## Illustrative Example

The following example problem illustrates how the two approximation techniques discussed above may be used to solve a simple one product, two region spatial price equilibrium model. Given the nonlinear demand and supply functions in each region and the fixed unit costs of transportation, the problem is to solve for the competitive equilibrium price, supply, and demand in each region and the interregional trade flows.

It is well known that the equilibrium supplies, demands, and trade flows may be obtained by maximizing the sum of the areas under the demand functions minus the areas under the supply functions minus transportation cost subject to the condition that both demands are satisfied by the available supplies [4, 6]. Let $f_1(x_1)$ be the inverse demand function and $f_3(x_3)$ be the negative of the inverse supply function in region 1 with $f_2(x_2)$ and $f_4(x_4)$ defined analogously for region 2. Further, let $f_5(x_5)$ be the unit transportation cost from region 1 to region 2 and let $f_6(x_6)$ be the unit transportation cost from region 2 to region 1 where $x_5$ and $x_6$ are the corresponding trade flows. Then this problem may be written as

(9)

$$\text{Maximize} \quad \sum_{j=1}^{6} F_j(x_j)$$

subject to

$$x_1 - x_3 + x_5 - x_6 \leqq 0$$
$$x_2 - x_4 - x_5 + x_6 \leqq 0$$
$$x_1, \ldots, x_6 \geqq 0$$

where

$$F_j(x_j) \equiv \int_o^{x_j} f_j(\xi_j)d\xi_j.$$

The nonlinear inverse demand and supply functions are assumed to be approximated by segmented linear functions as described in Table 1. Also appearing in Table 1 are the "individual" $g_{ji}$ functions. It should be noted that these are defined in accordance with the first mentioned approximation technique for region 1's demand and region 2's supply functions while they are based upon the alternative approximation technique for the remaining

**Table 1. Example problem**

*DEMAND FUNCTIONS*

*Region 1*

$$g_1(x_1) = \begin{cases} 14 - 4x_1; & 0 \leqq x_1 \leqq 2 \\ 8 - x_1; & 2 \leqq x_1 \leqq 4 \\ 6 - \frac{1}{2}x_1; & 4 \leqq x_1 \leqq 8 \\ \frac{10}{3} - \frac{1}{6}x_1; & 8 \leqq x_1 \end{cases} \qquad \begin{aligned} g_{11}(x_{11}) &= 14 - 4x_{11} \\ g_{12}(x_{12}) &= 6 - \frac{4}{3}x_{12} \\ g_{13}(x_{13}) &= 4 - x_{13} \\ g_{14}(x_{14}) &= 2 - \frac{1}{4}x_{14} \end{aligned}$$

*Region 2*

$$g_2(x_2) = \begin{cases} 11 - \frac{1}{2}x_2; & 0 \leqq x_2 \leqq 6 \\ 14 - x_2; & 6 \leqq x_2 \end{cases} \qquad \begin{aligned} g_{21}(x_{21}) &= 11 - \frac{1}{2}x_{21};\ x_{21} \leqq 6 \\ g_{22}(x_{22}) &= 8 - x_{22} \end{aligned}$$

*SUPPLY FUNCTIONS*

*Region 1*

$$-g_3(x_3) = \begin{cases} \frac{1}{2}x_3; & 0 \leqq x_3 \leqq 6 \\ -3 + x_3; & 6 \leqslant x_3 \leqslant 8 \\ [5, \infty); & x_3 = 8 \end{cases} \qquad \begin{aligned} g_{31}(x_{31}) &= -\frac{1}{2}x_{31};\ x_{31} \leqq 6 \\ g_{32}(x_{32}) &= -3 - x_{32};\ x_{32} \leqq 2 \end{aligned}$$

*Region 2*

$$-g_4(x_4) = \begin{cases} 3x_4; & 0 \leqq x_4 \leqq 2 \\ 2 + 2x_4; & 2 \leqq x_4 \leqq 3 \\ \frac{29}{4} + \frac{1}{4}x_4; & 3 \leqq x_4 \end{cases} \qquad \begin{aligned} g_{41}(x_{41}) &= -3x_{41} \\ g_{42}(x_{42}) &= -6 - 6x_{42} \\ g_{43}(x_{43}) &= -8 - \frac{2}{7}x_{43} \end{aligned}$$

*TRANSPORTATION COSTS*

$g_5(x_5) = -t_{12}$; minus the unit transportation cost from region 1 to 2

$g_6(x_6) = -2$ ; minus the unit transportation cost from region 2 to 1

Table 2. Simplex tableau for example problem

| $P_o$ | $w_1$ | $w_2$ | $z_{21}$ | $z_{31}$ | $z_{32}$ | $x_{11}$ | $x_{12}$ | $x_{13}$ | $x_{14}$ | $x_{21}$ | $x_{22}$ | $x_{31}$ | $x_{32}$ | $x_{41}$ | $x_{42}$ | $x_{43}$ | $x_5$ | $x_6$ | $(u,r)$ | $(v)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | | | | 1 | 1 | 1 | 1 | | | −1 | −1 | | | | 1 | −1 | | |
| 0 | | | | | | | | | | 1 | 1 | | | −1 | −1 | −1 | −1 | 1 | | |
| 6 | | | | | | | | | | 1 | | | | | | | | | I | |
| 6 | | | | | | | | | | | | 1 | | | | | | | | |
| 2 | | | | | | | | | | | | | 1 | | | | | | | |
| 14 | 1 | | | | | 4 | | | | | | | | | | | | | | |
| 6 | 1 | | | | | | 4/3 | | | | | | | | | | | | | |
| 4 | 1 | | | | | | | 1 | | | | | | | | | | | | |
| 2 | 1 | | | | | | | | 1/4 | | | | | | | | | | | |
| 11 | | 1 | 1 | | | | | | | 1/2 | | | | | | | | | | |
| 8 | | 1 | | | | | | | | | 1 | | | | | | | | | −I |
| 0 | −1 | | | 1 | | | | | | | | 1/2 | | | | | | | | |
| −3 | −1 | | | | 1 | | | | | | | | 1 | | | | | | | |
| 0 | | −1 | | | | | | | | | | | | 3 | | | | | | |
| −6 | | −1 | | | | | | | | | | | | | 6 | | | | | |
| −8 | | −1 | | | | | | | | | | | | | | 2/7 | | | | |
| $-t_{12}$ | 1 | −1 | | | | | | | | | | | | | | | | | | |
| −2 | −1 | 1 | | | | | | | | | | | | | | | | | | |

functions. The simplex tableau for solving the approximating problem by Wolfe's [7] modified simplex algorithm is provided in Table 2. Table 3 provides the solutions, one for each assumed value of the unit cost of transportation from region 1 to region 2, $t_{12}$, together with the implied regional demand and supplies $x_1, \ldots, x_4$. For example, when $t_{12} = 2$, the equilibrium price of the product is $w_1 = 4.86$ in region 1 and $w_2 = 6.86$ in region 2; region 2 produces $x_4 = x_{41} + x_{42} + x_{43} = 2.29 + 0.14 + 0.0 = 2.43$ units of the product and consumes $x_2 = 7.14$ units, the remaining $4.71 = x_5$ units being imported from region 1. As the unit transport cost between region 1 and 2 is increased from 2.0 to 4.3, the solutions for $x_1, \ldots, x_4$ change and the solutions move from segment to segment along the approximating functions $g_j(x_j)$. This movement is achieved by successive $x_{jl}$'s entering or leaving the optimal solution for the quadratic programming problem.

## Summary

In this paper a simple method for computing approximate solutions for nonlinear non-quadratic separable programming problems involving linear constraints has been developed. The method is to create an approximating problem obtained by replacing each term in the separable

**Table 3. Solutions for example problem**

| VARIABLE | ASSUMED VALUE FOR $t_{12}$: 0.0 | 1.0 | 2.0 | 4.0 | 4.3 |
|---|---|---|---|---|---|
| $x_{11}$ | 2.00 | 2.15 | 2.29 | 2.50 | 2.55 |
| $x_{12}$ | * | .45 | .86 | 1.50 | 1.65 |
| $x_{13}$ | | | | | |
| $x_{14}$ | | | | | |
| $x_{21}$ | 6.00 | 6.00 | 6.00 | 6.00 | 5.80 |
| $x_{22}$ | 2.00 | 1.60 | 1.14 | | |
| $x_{31}$ | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $x_{32}$ | 2.00 | 2.00 | 1.86 | 1.00 | 0.80 |
| $x_{41}$ | 2.00 | 2.13 | 2.29 | 2.67 | 2.70 |
| $x_{42}$ | | .07 | .14 | .33 | .35 |
| $x_{43}$ | | | | | .35 |
| $x_5$ | 6.00 | 5.40 | 4.71 | 3.00 | 2.40 |
| $x_6$ | | | | | |
| $w_1$ | 6.00 | 5.40 | 4.86 | 4.00 | 3.80 |
| $w_2$ | 6.00 | 6.40 | 6.86 | 8.00 | 8.10 |
| $x_1$ | 2.00 | 2.60 | 3.15 | 4.00 | 4.40 |
| $x_2$ | 8.00 | 7.60 | 7.14 | 6.00 | 5.80 |
| $x_3$ | 8.00 | 8.00 | 7.86 | 7.00 | 6.80 |
| $x_4$ | 2.00 | 2.20 | 2.43 | 3.00 | 3.40 |

* The absence of a value for a variable means that it takes a zero value since it did not appear in the basic solution.

function by a continuous and smooth piece-wise quadratic function. The solution to this problem is then obtained from the solution of a third problem which is equivalent to the approximating problem and which is a quadratic programming problem. Thus quadratic programming algorithms may be used to provide approximate solutions for separable programming problems.

The technique is applicable to a wide range of problems in economics. Spatial and temporal equilibrium models of markets, activity analysis models involving nonlinear product demand functions, monopolistic models, and nonlinear transportation models are obvious candidates for solution by this technique. Often these models, discussed in detail by Takayama and Judge [5], involve a large number of linear production and allocation activities and somewhat fewer variables that enter the objective function nonlinearly. If the number of nonlinearities is relatively small, then the method proposed in this paper should be particularly useful since it eliminates the need to use a more general nonlinear programming algorithm.

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# Communications

## TOWARD A BETTER SYSTEM OF DATA FOR THE FOOD AND FIBER INDUSTRY

The purpose of this paper is to stimulate further thought and discussion about ways to improve our system of economic intelligence for the food and fiber industry. At least it might alert some people in our profession to the limitations of commonly used data, especially data on farm income, farm assets and debts, and marketing costs and margins.

This paper focuses on *economic* data for the food and fiber industry rather than *social* data for farm and rural people. This focus recognizes a sharp distinction between data relevant to the business of agriculture and data relevant to farm households and people. We have equated farms and farm families for far too long. We are concerned here chiefly with measures of structure and performance of the food and fiber industry, costs and returns to participants and to resources, and assets and debts of the industry.

Some types of industry data can be collected, summarized, and reported without specific reference to firms or business establishments. Numbers of livestock, acreages of crops, volumes of production, and even prices of produce in specific markets can be observed and recorded regardless of who owns them or of how they were produced. Improvements in accuracy and coverage of such data have been and will continue to be made. But they are not the most bothersome part of our economic data now, and they are not discussed specifically in this paper.

### Present Data Systems

Some of the shortcomings of present data systems have been well documented elsewhere, so no extended discussion is needed here [1, 4, 5, 7]. Recent literature on agricultural data stresses both inaccuracies and inadequacies. Concern over the state of our data grows partly out of the fact that the structure and operation of the food and fiber industry has changed so drastically in recent decades that traditional data series do not describe the industry accurately. They fail to provide information needed for private and public decisions; they may provide information that is dangerously wrong. As the food and fiber industry becomes more highly commercialized, more highly integrated, and more finely tuned, the need increases for more accurate, more timely, and more adequate economic data. Moreover, as analytical tools become more powerful, data must become more appropriate and reliable. When economists build rigid analytical models to use on flabby data, they may fail to exploit fully their analytical tools, and they may produce dangerously erroneous inferences from their analyses.

Traditional agricultural data—at least those of concern in this paper—were designed chiefly as economic indicators of the welfare of farmers. They served a useful purpose in the past when agricultural policy issues focused largely on farms and farmers. Even for this purpose, numerous inadequacies and inaccuracies are evident now to producers and users of the data. Now we must have a broader focus. The businesses that supply inputs to farming and the businesses that assemble, process, and distribute farm products to consumers are a larger, and often more critical, part of the food and fiber industry than is farming itself. Yet we have no consistent body of data covering the whole of the food and fiber industry. Some of the necessary data can be gleaned from the Census of Manufactures, Census of Business, and other public and private sources. But these must be spliced and patched for many of our more important purposes.

Single purpose economic indicators have been developed over the years, each somewhat independent of all others and each having its own conceptual base which makes it only accidentally consistent, if at all, with others. While single purpose economic indicators are useful, management of a modern industry demands more sophisticated intelligence.

Even as economic indicators, traditional data series are increasingly suspect. Farm firms and households no longer have a meaningful identity with each other [2]. Firms and functions are now divided differently and in a more complicated fashion than formerly. For example, farmers once farmed and relied mostly on farming for income. Now many others engage in farming one way or another, and farmers themselves get at least half their income from nonfarm sources. Intrasector and intersector exchanges also play a different role in modern agriculture. Inputs to the food and fiber industry are more varied and more complex, and outputs are more complicated and follow diverse paths to the final consumer. Moreover, the relationships between the food and fiber industry and the rest of the economy are more intricate, more intimate, and certainly more critical for the industry itself, as well as for suppliers and consumers, than ever before.

Without belaboring the point further, traditional agricultural data systems lag modern needs; the evolution of the system has not kept pace with the revolution of the industry. This casts no criticism on the producers of traditional data and economic

indicators. They have done marvelously well with the resources available to them. We simply must now invest both intellectual capital and money to build a data system that more properly meets modern needs.

## Alternative Data Systems

Without precipitously abandoning traditional series of data, we need urgently to develop an internally consistent system of accounts for the food and fiber industry. We must develop meaningful linkages between these accounts and the economic intelligence available for other sectors of the economy, and we must define units of observation and useful aggregates of data congruent with the logic of a system of accounts. Finally, we must derive ways to implement a redesigned system. We must visualize, if possible, what we want a system of economic data to do. Only then can the design be meaningful and only then will suggestions for procedure make sense.

Parenthetically, one must admit that no system of economic data can serve all purposes perfectly. No on-going system can eliminate the need for special studies to gather data and to make analyses of unique problems. Probably no analyst ever had all the data he wanted in the form and detail he wanted it—even though he may have had more data than he could properly use for the purpose in hand.

The food and fiber industry is defined here as the entire range of economic activities directed at supplying this nation (and exports) with food, fiber, and certain other products like tobacco and mint. It might include such products and services of land as timber and recreation. It might exclude the man-made fibers and foods of "non-agricultural" origin. Functionally the industry extends from supplying inputs for farming at one end to selling final goods and services to consumers at the other. This definition needs refinement so that data collectors can know precisely what economic units and functions to observe and what information to record about them.

Meaningful subparts of the industry must be defined also both for guiding collection of data and for guiding preparation of aggregates of data. These subparts should be based on products or services produced, on the types of institutions ("establishments," "firms," "sectors," as in the "poultry sector" or the "feed grain sector"), on the functions performed (farming, transportation, packing), on geographical location, on types of resources used, and on tenure or types of ownership. Doubtless additional or other bases for classification would be meaningful. Precision in the taxonomy of the industry lies ahead.

Data should provide a barometer for monitoring the economic health of the industry and its meaningful subparts. They should relate the food and fiber industry to the economy as a whole. They should help people in the industry make better economic decisions. They should be the raw material for identification and diagnosis of problems, and they should permit evaluation of alternative courses of action.

These specifications suggest an internally consistent system of accounts that would monitor the flows of commodities and services, finances, and physical resources into the industry, through the industry, and out of the industry. These accounts should include an input-output account, a capital flows account, a capital stocks account, and supply-utilization accounts. Not all accounts need apply in equal detail to all subparts of the industry. As a minimum, input-output accounts, capital flows accounts, and capital stocks accounts are needed for the farm inputs sector, the farming sector, and the product handling sector of the industry. Within these sectors as much detail as we can afford would be desirable based on types of products or services, types of institutions and firms, types of functions, and geographical location.

Such a system of accounts, if properly developed and kept up, should provide the basis for more reliable answers than we now have to such questions as: What is the value added to food and fiber products by each vertical stage in production and marketing? What are the returns to resources and people in each stage? What changes are occurring in input-output relationships, in types of inputs, in volume of product, and in flow of funds and products? What is the structure and "functioning" of the industry, and how is it changing? How is the food and fiber industry getting along in relation to its own past or in relation to other parts of the national economy? These and dozens of similar questions readily come to mind. More importantly, such a system of accounts should be ". . . designed to give empirical content to an image of the functional relationships that define the total system itself (or some important set of total system relationships). They provide an information base for total system guidance and management" [3].

The system of accounts visualized here may not be as revolutionary as one might suspect at first glance. Present data dealing with farm income, farm finance, farm real estate, marketing costs and margins, and other similar series as well as parts of the census of manufactures and businesses and agriculture must serve as the basis for any new system of data. The important innovation needed is to build a system that is internally consistent and that has logical and useful relationships among the parts and between them and other information about the national economy. Data in the system must share common units of observation, must meet a set of consistency criteria based on a logical structure of components which can support the analyses of interrelationships, and must have a capability for supporting projections of their own level and structure by use of macro-economic forecasting models.

## A Challenge to Agricultural Economists

Dr. Harry Trelogan, Administrator of the Statistical Reporting Service, USDA, has challenged agricultural economists to develop their specifications for more adequate and more accurate data. He says we must tell the statisticians what we want. I repeat and emphasize his challenge.

Some economists regularly use the publicly available series of data on agriculture with appalling equanimity—without even a reference to Agricultural Handbook 365 [6]. Others complain of inadequacies of data but have done little to develop new systems. This paper is an invitation to become involved in the process of developing a better system of data for the food and fiber industry. Hopefully, it will prompt response from others in the profession.

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# THE *JOURNAL* AS A REFERENCE SOURCE—1959–1968: COMMENT

Discussion in this most interesting paper with respect to *AJAE* prize winners is misleading. As supervisor of research covered by a number of prize-winning publications in the late 1950's, I am aware that most were landmarks in their field and were "so all-encompassing . . . as to eliminate the need for any further writings on the subjects which they covered" [1, p. 459], at least until 10 years or so of data had accumulated under a changed economic structure. Three USDA Technical Bulletins that come to mind are those by Meinken [3] on wheat, Gerra [2] on eggs, and Rojko [4] on dairy products. I doubt that more than two or three publications of any kind in these fields have been published in the intervening 10–15 years. Roy and Johnson [5] in 1973 published an updated version of a model for eggs, citing Gerra as one of two non-data-source references.

Related to this is the subject matter of the 25 references cited most often in *AJAE* (Table 9 in the original paper). Most deal with methodology, broad topics, or broad aspects of policy. Thus they lend themselves to citation in many types of papers. Nerlove (who was on my staff briefly) believed in maximizing publications per unit of research. Papers 6, 15, 22, and 25 on the list all deal essentially with the same topic: Paper 10 covers the same basic methodology in a different applied area. Had Nerlove published only his book in the supply analysis field, thus forcing citation of a single publication, the total likely would have been 54 (20 + 13 + 11 + 10), placing him first on the list. This is where I think he belongs in terms of a methodological contribution to agricultural research.

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# THE *JOURNAL* AS A REFERENCE SOURCE—1959–1968: COMMENT

Finley and Barger set out to determine the extent to which information appearing in the *Journal* is used (reused) to further someone else's research [1]. Or, as they stated it precisely, "to take a critical look at this *Journal* to determine the source value of its articles." For reasons of economy they restricted their survey to the footnotes and bibliographies of material published in *AJAE* during the period 1959–1968. The stated assumption was that "the most likely place to find references to a particular source is the source itself."

Although the authors report in detail the results of their survey, they leave the reader without the benefit of their conclusions with respect to the question raised. This note represents an attempt by one reader to draw conclusions from the information presented.

The sample consisted of 1,864 articles for the period 1959–1968, containing a grand total of 13,272 reference citations. Of these, 1,057 citations were to *AJAE(JFE)* articles irrespective of the date of publication, and 664 citations were to *Journal* articles published between 1959 and 1967. The data thus imply that less than 40 percent of the 1,664 *Journal* articles published from 1959–1967 were ever cited in another *AJAE* article. The 13,272 reference citations were tabulated to determine the 38 most cited authors. The 1,864 *AJAE* articles were also tabulated by author. The number of *Journal* articles authored between 1959 and 1968 by the 38 most cited authors ranged from six to 18 articles, although the "most cited" ranking referred to how many times these authors had been used as a reference in, not published in, the *Journal*. The analysis shows that none of the 10 most frequently cited references were from the *AJAE(JFE)*, although the *Journal* did place eight in the top 25. And finally Finley and Barger show that of the 22 Best *Journal* Article award winners, three were not cited in other *AJAE* articles and only four were cited five or more times.

In Tables 2, 3, 6, and 8 Finley and Barger do not provide information pertinent to the evaluation of *AJAE* as a reference source, but rather address the tangential question of the sources of references used by *Journal* authors. Table 6, the 38 authors most cited, raises an additional issue, although it was not discussed or analyzed by the authors. Although the purpose of a journal is to enable members of the profession to read what others have written, some of our 38 most cited authors appear to practice this more successfully than others. In fact a few of the 38 most cited authors appeared to be directly responsible for their own success. Table 1 in this Comment (computed from the data in the authors' Table 6) compares how the leading "self-citers" would rank using three different criteria and the percentage of their total citations for which they are themselves responsible.

In summary the conclusions with respect to the question raised by Finley and Barger might be these:

1. Consistent with the finding of an earlier study that less than 8 percent of our literature is published in journals [2], less than 8 percent of the reference sources of *AJAE* articles are other *AJAE* articles.
2. In spite of the fact that what is printed is the best of what is submitted, less than four of each 10 *Journal* articles are cited, as *Journal* references, and less than half of these four are cited more than once.
3. Depending upon how stringent one's definition of a "classic" in the literature of the profession,

**Table 1. The 10 authors most frequently cited by self**

| Author | Citations by Self* | | | Citations by Others | | Total Citations | |
|---|---|---|---|---|---|---|---|
| | No. | Rank | Percent of Total | No. | Rank | No. | Rank |
| Theodore W. Schultz | 23 | 1 | 14 | 136 | 2 | 159 | 2 |
| Vernon W. Ruttan | 21 | 2 | 27 | 57 | 8 | 78 | 7 |
| Karl A. Fox | 20 | 3 | 38 | 32 | 25 | 52 | 12 |
| Zvi Griliches | 18 | 4 | 13 | 117 | 3 | 135 | 3 |
| Earl O. Heady | 17 | 5 | 9 | 177 | 1 | 194 | 1 |
| Emery N. Castle | 12 | 6 | 46 | 14 | 38 | 26 | 33 |
| S. Ciriacy-Wantrup | 12 | 7 | 27 | 32 | 24 | 44 | 17 |
| Harold F. Breimyer | 11 | 8 | 26 | 31 | 26 | 42 | 19 |
| Richard H. Day | 8 | 9 | 23 | 27 | 32 | 35 | 26 |
| Wayne Fuller | 7 | 10 | 23 | 16 | 37 | 23 | 37 |

* Due to the design of the study, this ranking of authors by the frequency of self-citation is limited to those who published in *AJAE*. It may be that others of the 38 authors also have a high incidence of self-citation, but it occurs in other journals. Of course, several of the 38 authors most cited did not publish in any media during the study period 1959–1968 for various reasons.

a varying number of *Journal* articles reach such a level of distinction:

(a) None of the 10 references most often cited in *AJAE* from 1959 to 1968 were *AJAE* articles;

(b) Eight of the 25 references most often cited in *AJAE* from 1959 to 1968 were *AJAE* articles;

(c) Two *Journal* articles of the 1,664 published during 1959–1967 made the list of 25 most cited references from 1959 to 1968.

4. Recipients of the Best *Journal* Article award have a probability of citation approximately six times that of the average *Journal* article.

The conclusions with respect to other information in the Finley-Barger article might be these:

1. Roughly two-thirds of the references and authors cited in *AJAE* articles are unique citations—not repeated in other *AJAE* article citations.
2. Several of our leading *Journal* authors depend heavily upon their own published literature as reference sources.
3. The list of five authors most frequently cited is unaffected in content, but not in order, by whether the listing criterion is sole authorship only or inclusive of joint authorship.

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# THE *JOURNAL* AS A REFERENCE SOURCE—1959–1968: REPLY

We acknowledge and appreciate comments by Richard J. Foote and A. Barry Carr. Each addresses different problems, so first with regard to Foote's comments: We agree—although there is a serious question whether items in Table 9 are really of an additive nature; but we must emphasize that the rankings were not a purpose but rather a result of the exposition. Our poor attempt at levity ("Surely they ['the prize winners'] cannot have been so all-encompassing and profound as to eliminate the need for further writings on the subjects which they covered" [1, p. 459]), however, may be lost on some readers. We certainly were not trying to praise or demean any particular article but were addressing the issue of the usefulness of the *Journal* as a research tool or source. Reuse of material published doubtlessly reflects somewhat on initial selection standards. If any article in the *Journal* exhausts possible commentary in a particular field, perhaps the field has been defined incorrectly or at least defined too narrowly to have deserved exposure at all. Few in our profession accede to Pascal: "All the good maxims have been written. It remains only to put them into practice." It perhaps does come down to an issue of quality versus utility although we would argue that these are complementary rather than competing ends. It is an open question, but sometimes one must wonder if a major criterion is style rather than concern. Since items published in the *Journal* are purportedly the best in the field, obviously future articles on the same subject should mention their predecessors. If they do not, perhaps it is because the original articles lacked the profundity commonly assumed.

Carr's comment concisely and effectively summarizes some of the factual content of the article. In the main we have no quarrel with the conclusions he derives. Further, Carr gives a positive start to "conclusions" based on this article—conclusions of opinion, not necessarily fact. This is what we left to be discerned by the reader.

Some of these conclusions could be expanded, perhaps modified. At any rate, the summary or conclusions such as those suggested by Carr—and those of other individual readers—are precisely what we sought with our somewhat enigmatic, obscure ending. We had hoped that by not giving the traditional summary, the broader issues—the real point of the paper—would not be camouflaged by a cloud of figures.

All in all, it is a thorough and perceptive comment. A couple of items do need clarification, however. Carr concludes that "less than four of each 10 *Journal* articles are cited, as *Journal* references, and less than half of these four are cited more than once." The latter part of the statement may be true by inference (since about 13 percent of all references are cited more than once) but cannot be deduced from data presented. Also we did not figure the probability of citation of an average *Journal* article; however, 86 percent of the Best *Journal* Article winners prior to 1968 had been cited as references.

Maybe Dr. Carr is viewing the forest unobscured by the trees that plague authors. These data may very well be included in a disguised form which eluded even us. If so, perhaps he should change his specialty to cryptography.

The *Journal* is the profession's main medium and method of communication and has as a premise quality, readability, interest, and value in its articles. The real question appears to be: Is the role of the *Journal* being fulfilled or *suum cuique*? We should be disappointed to learn that authors are not using this valuable reference resource as much as might be expected. Writers here certainly need not fear the validity of the references to former articles, and again we reiterate that it is incumbent upon the author to study what has previously been written (on his subject) in the publication for which the material is intended. Since so few (relatively) *Journal* articles are cited, maybe all the *Journal* articles did explore net new fields. But if they did, then they probably would be quoted in later articles. Thus, the closing of a literary circle! Apropos is Henry Margenau's lament [2, p. 117]: "What is discouraging . . . is not the goal they seek but only in their lack of success in attaining it so far."

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## ON THE TIMING AND APPLICATION OF PESTICIDES: COMMENT*

In a recent article, Hall and Norgaard [1] presented a single treatment, two-variable model for optimizing a pest management strategy. By controlling the timing and the pesticide quantity to be applied, they offered an extension of Headley's single-variable model [2]. We made an attempt to apply the model to a specific case. To do this, one must make a choice of a kill function, which was left in implicit form given by equations (2.2a) and (2.2c) [1, p. 199]:

$$K = K^* [X,P(t_i)] = K^*(X,P_o e^{rt_i}) = K(X,t_i).$$

Some guidance for the selection of the explicit kill function is given in footnote 3 [1, p. 201]: namely $K_{xx} < 0$ and the statement ". . . this model has a unique interior solution if the following three plausible assumptions are valid: the number of pests killed increases with an increase in the quantity of pesticide applied; the number of pests killed increases at a decreasing rate; and a given quantity of pesticide will kill more pests if the pest density increases." It will be shown here that these conditions, though necessary, are not sufficient. In fact, choosing a wide range of kill functions linearly related to the pest population density level $P(t)$, which was, for example, the choice of Shoemaker [4] and described by Knipling [3, p. 9], forces a non-interior solution. However, under alternative choices for the kill function, the model does yield an interior solution. An example is provided in the last section.

### A Non-Interior Solution

Assume the kill function to be a linear function of the pest population:

$$(1) \qquad K(X,t_i) = P(t)\,F(X) = P_o e^{rt_i} F(X).$$

$F(X)$ is an arbitrary function satisfying the natural conditions $F'(X) > 0$, $F''(X) < 0$ (Diminishing returns function). The formula (1) yields

$$(2) \qquad K_{t_i}(X,t_i) = r\,K(X,t_i)$$

and from (2.6b) of [1, p. 200]

$$(3) \qquad \Pi_{t_i} = -\,\beta b K(X,t_i).$$

$\Pi_{t_i}$ vanishes only when $K(X,t_i) = 0$, which means that we kill no pest! On the other hand, $\Pi_{t_i} < 0$, which means that for fixed $X$, the profit is a decreasing function of the time $t_i$ where the insecticide is applied and, therefore, the maximum profit is achieved if the insecticide is applied at $t_i = 0$ (a non-interior solution). The optimal quantity $X$ of pesticide to be applied will be obtained by substituting $t_i = 0$ in (2.7a) of [1, p. 200].

### A Graphical Interpretation

The result of the previous paragraph can be illustrated graphically. In Figure 1 the pest population level is represented in two cases: In *Case 1* (broken line) the pesticide is applied at the start. In *Case 2* (solid line) the pesticide is applied at some time $t_i > 0$.

Notice that at $t = t_i$, the pest population levels are the same for both cases, namely, $P_o e^{rt_i}[1 - F(X)]$. Therefore, the portions of the two curves to the right of the line $t = t_i$ coincide. The damage, which is proportional to the area under the respective population curves, is greater in Case 2 by the shaded area, $P_oCDB$, illustrating the previous result.

### Increasing the Efficiency of the Kill Function

The Hall and Norgaard model can lead to an interior solution, as claimed by the authors, if the assumption of linearity of $K$ as a function of the pest population is no longer made. Assume, for example, that by application of the pesticide at $t_i$, the pest population drops to a point $D'$ below $D$ in Figure 1. The pest population is now shown by the mixed line $P_oCD'E'$, and we see that a compensation to the shaded area is obtained as represented by the dotted area. This suggests that some optimum might be achieved at some interior point. Let, for example, the kill function be:

$$(4) \qquad K(X,t_i) = P(t)^{\gamma} F(X) = P_o{}^{\gamma} e^{\gamma r t_i} F(X),$$

which leads to

$$(5) \qquad K_{t_i} = \gamma r\, K(X,t_i),$$

and from (2.6b) of [1, p. 200]

$$(6) \qquad \Pi_{t_i} = -\beta b K(X,t_i)[\gamma - (\gamma - 1)\, e^{r(t_h - t_i)}].$$

$\Pi_{t_i} = 0$ yields the solution $K(X, t_i) = 0$ which is not interesting, or;

$$(7) \qquad e^{r(t_h - t_i)} = \gamma/(\gamma - 1).$$

This has a solution $t_i (0 < t_i < t_h)$ if and only if $\gamma > 1$, which means that the efficiency of the pesti-

* The authors are indebted to Darwin C. Hall and Richard N. Norgaard for their constructive suggestions on earlier drafts of this comment. The work herein reported was funded in part by an I.B.P.-sponsored project entitled, "The Principles, Strategies and Tactics of Pest Population Regulation and Control in Major Crop Systems." Funds were provided by C.S.R.S., NSF, and by ARS-USDA under cooperative agreement 12-14-100-11, 194(33).

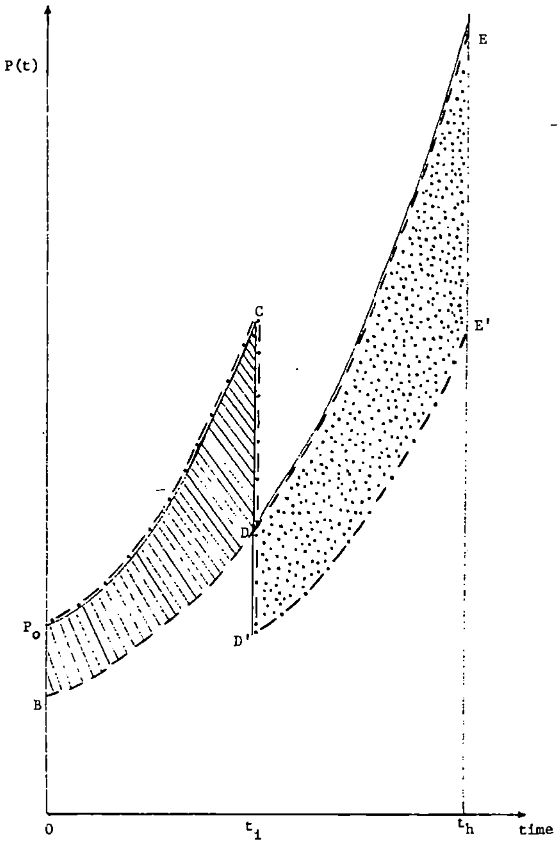


**Figure 1. Comparison of pest population levels**

cide increases with the population density. It is easily seen that if $t_i$ satisfies (7), it satisfies also:

$$\Pi_{t_i x} = \Pi_{x t_i} = 0, \quad (8)$$

$$\Pi_{t_i t_i} = -\beta b \gamma r K(X, t_i) < 0, \quad (9)$$

the assumption $F''(X) < 0$ yields

$$\Pi_{xx} < 0 \quad (10)$$

as noticed in [1, p. 201], and, therefore,

$$\begin{vmatrix} \Pi_{t_i t_i} & \Pi_{t_i x} \\ \Pi_{x t_i} & \Pi_{xx} \end{vmatrix} > 0 \quad (11)$$

which together with (9) and (10) shows that the critical point, obtained from the equations (2.7a) and (2.7b) of [1, p. 200], is a maximum.

In conclusion, Hall and Norgaard developed a very interesting model, although it requires some further specification to become useful. We believe that the specification of a non-linear kill efficiency with respect to the population level is only one such assumption which forces an interior solution. Other model modifications could also guarantee an interior solution.

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# ON THE TIMING AND APPLICATION OF PESTICIDES: REPLY

We wish to thank Borosh and Talpaz [1] for pointing out that footnote 3 in Hall and Norgaard [2] should read, "Summarizing, this model has a unique interior solution *only* if the following three plausible assumptions are valid. . . ." Several other omissions deserve mention: (1) $\beta$ is the price of the crop; (2) $t_0$, the planting time, is zero throughout; and (3) the right-hand side of equation (2.7b) in [2, p. 201] should be multiplied by $-b\beta/r$. However, there are a few points that bug us about the comment by Borosh and Talpaz [1].

First, we never meant for our model to be "applied." Our paper was a basic exploration of the definition of the threshold. In our conclusion we stated that our model "provides rigor to the definition of the concept of economic threshold but is too simple for practical application." Second, we would qualify the following sentence by Borosh and Talpaz [1]: "In fact, choosing a wide range of kill functions linearly related to the pest population density level $P(t)$, which was, for example, the choice of Shoemaker [4] and described by Knipling [3], forces a non-interior solution."

Equation (11) in Borosh and Talpaz [1] can be written as:[1]

$$(1)\qquad \left(\frac{\beta b}{r}\right)^2 [e^{r(t_h-t_i)}-1]^2$$

$$[K_{xx}(X,t_i)K_{t_it_i}(X,t_i) - K_{xt_i}{}^2(X,t_i)]$$

$$+ e^{r(t_h-t_i)} \left\{ 2\beta b\alpha K_{xt_i}(X,t_i) - (\beta b)^2 K(X,t_i)K_{xx}(X,t_i)[e^{r(t_h-t_i)}+1] - \frac{\alpha r}{[e^{r(t_h-t_i)}-1]} \right\} > 0.$$

$\Pi_{xx} < 0$, $\Pi_{t_it_i} < 0$, and (1) are second-order sufficient conditions for a local maximum at the point implicit in equations (2.7) in Hall and Norgaard [2]. As pointed out in footnote 3 in [2], the first condition implies $K_{xx}(X,t_i) < 0$. It is sufficient for the second condition that $K_{t_it_i}(X,t_i) < 0$. Further, when the first condition holds, the first term in (1) is strictly positive if $K_{t_it_i}(X,t_i) < 0$. If we assume that applying slightly more pesticide when the pest population is slightly more dense (intuitively, a situation with a high probability of more pests coming into contact with the pesticide) causes an increase in the number of pests killed, or $K_{xt_i}(X,t_i) > 0$, then the second term in (1) is composed of two positive parts and one negative part,

$$-\frac{\alpha r}{[e^{r(t_h-t_i)}-1]} \equiv -\alpha Q.$$

Note that, for reasonable values of $r$ and $t_h$, $Q$ is less than 1. Hence, as long as the price of pesticide $\alpha$ is small enough so that $\alpha Q$ is smaller than the other two terms in braces, $K_{t_it_i}(X,t_i) < 0$ is a sufficient condition for an interior solution when $K_{xx}(X,t_i < 0$. Borosh and Talpaz [1] consider a kill function where $K_{t_it_i}(X,t_i) > 0$ for any nonzero application of pesticide. These kill functions are of the form

$$(2)\qquad K(X,t_i) = G[P(t)]\,F(X).$$

However, note that whether or not $K_{t_it_i}(X,t_i)$ is greater or less than zero only depends on $G[P(t)]$ which, in turn, depends on the form of the pest population growth equation. This leads to the consideration that perhaps the range of kill functions entertained by Borosh and Talpaz is not so wide. Certainly they have not presented any evidence of the relative importance and frequency of kill functions which yield non-interior solutions. Although Knipling's [3] comments are consistent with the separable form of the kill equation in (2) when $G[P(t)] = P(t)$, the separability of the population from $F(X)$ seemed to be taken as a matter of numerical convenience in Knipling's discussion. Further, his comments do not necessarily imply this functional form. Finally, Shoemaker [4] did not apply this form to the unrealistic exponential population growth equation we originally used. Any population growth equation which does not grow forever will have a range over which $K_{t_it_i}(X,t_i) < 0$.[2] The important question is which range is relevant from the first-order conditions.

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# SPARSE DATA, CLIMATIC VARIABILITY, AND YIELD UNCERTAINTY IN RESPONSE ANALYSIS: COMMENT

In a recent article in this Journal, Anderson [1] continues his crusade for the adoption in response analysis of methodological procedures which utilize both prior and experimental information and account for the pervasive elements of uncertainty. With this we are in full sympathy. Within his paper, however, Anderson has made several oversights which warrant attention.

Anderson is concerned with determining the optimal levels of factor use in a stochastic production process for crop yield when the available information on the process is sparse. Anderson's contribution is the proposal of a method for determining empirical functions relating moments of the profit distribution to factor levels. The procedure involves an intermediary stage in which moments of the yield response distribution are related to factor levels by first using Schlaifer's rule to construct cumulative distribution functions (CDF) of yield response and then calculating their moments, e.g., mean and variance.

As the CDF's have been derived, "variance of response" is somewhat of a misnomer. Strictly it is the variance of conditional predicted outputs, i.e., the variance of predictions conditional on type of year or weather. This variance is a composite variance of year differences and of the uncertainty in the predictions which are only estimates and does not measure the variance of response; nor does it measure the variability of interest to the decision maker, namely the variability of predicted response.

To elucidate these points, consider the following random effects model:

$$Y_{ij} = Y_{..} + Y_{i.} + \epsilon_{ij}$$

where

$Y_{ij}$ is the yield from unit (e.g., an acre) $j$ in year $i$;
$Y_{..}$ is an overall mean
$Y_{i.}$ is a year effect such that $Y_{i.} \sim IID\ (0, \sigma_y^2)$;

and

$\epsilon_{ij}$ is a random within year effect such that $\epsilon_{ij} \sim IID\ (0, \sigma_\epsilon^2)$.

Anderson's model is more complex than this in that it also involves fixed effects associated with the input factors, but this simple, didactic example serves well to illustrate the salient points.

In general neither $Y_{..}$, $\sigma_y^2$, nor $\sigma_\epsilon^2$ will be known. Instead, as in Anderson, we may have $r$ observations in each of $n$ years. An analysis of variance of these data would yield estimates of the within year variance $\sigma_\epsilon^2$, and of the composite year effect $\sigma_\epsilon^2 + r\sigma_y^2$, which is $\sigma_\epsilon^2/r + \sigma_y^2$ on a mean yield basis; it is this that Anderson's variance of response estimates.

The decision maker interested in the variance of profits will be concerned with the total variability of response confronting him; this is comprised not only of how the mean yield of a population of units will vary from year to year, but also of how the true yield of each production unit varies from the mean and of the uncertainty attached to the mean itself. In terms of the estimates obtained from analysis of the available data, the predicted yield from an acre is

$$\hat{Y}_{ij} = \hat{Y}_{..} + \hat{Y}_{i.} + \hat{\epsilon}_{ij},$$

with $$E(\hat{Y}_{ij}) = Y_{..},$$

and $$V(\hat{Y}_{ij}) = V(\hat{Y}_{..}) + V(\hat{Y}_{i.}) + V(\hat{\epsilon}_{ij}).$$

From the analysis of variance we will have estimates of these three variances. Assuming, for simplicity, that we have sufficient degrees of freedom, we may write,

$$\begin{aligned} V(\hat{\epsilon}_{ij}) &\approx \sigma_\epsilon^2 \\ V(\hat{Y}_{i.}) &\approx \sigma_y^2 \\ V(\hat{Y}_{..}) &\approx \sigma_y^2/n + \sigma_\epsilon^2/nr. \end{aligned}$$

Hence,

$$V(\hat{Y}_{ij}) \approx \sigma_y^2/n + \sigma_\epsilon^2/nr + \sigma_y^2 + \sigma_\epsilon^2.$$

This compares with the quantity estimated by Anderson, namely $\sigma_y^2 + \sigma_\epsilon^2/r$. Thus he omits three terms, $\sigma_y^2/n$, $\sigma_\epsilon^2/nr$, and $\sigma_\epsilon^2$, and includes $\sigma_\epsilon^2/r$. In general, Anderson will underestimate the variance of the CDF of response relevant to the decision maker, the amount of underestimation being greater the more sparse the data.

The importance of these omissions from the decision maker's point of view has not as yet been studied by us, but it would seem that, if not important in terms of loss in utility, they are in terms of the logic and rationale of decision analysis.

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# SPARSE DATA, CLIMATIC VARIABILITY, AND YIELD UNCERTAINTY IN RESPONSE ANALYSIS: REPLY

The critique of Drynan and Lugton is symptomatic of the difficulties encountered in empirical work when the domain of the economist is extended to include risk. In its most general form, their criticism runs as follows: While it's a good idea to account for risk (= uncertainty) in economic modeling, we have to be careful to recognize and account for the uncertainty about our quantification of the uncertainty faced by decision makers. Thus, for instance, in formulating a risk programming model, does the specification of parameters of probability distributions adequately reflect the fact that these specifications are only estimates of appropriate parameters?

The specific point they criticize in my work is the estimation of distributions on the basis of fractile estimates which are predictions from yearly response functions. They claim that I have estimated these distributions inappropriately because I did not take account of the variance of these (conditional mean) predictions (representing the uncertainty in the estimated function) or of the variance of individual observations. The latter variance is a composite of the intrinsic biological variation encountered in small experimental plots and the imperfect fit of empirical response functions. The relationship between small plot variation and variation in whole fields (i.e., the real-world decision units) seems unclear and well worthy of earnest empirical attention. My approach implicitly assumed that the conditional mean response from experimental plots gave the best indication available of yearly response in whole fields.

However, Drynan and Lugton have convinced me that my smoothing procedure omitted some legitimate risk. How important is my omission is difficult to assess because of the multistage and subjective nature of my sparse-data estimational procedure. One case was studied in an informal sampling experiment by comparing the CDF derived from the originally described procedure (based on predicted means) with those obtained by a modification of the procedure that used simulated predictions. The simulated predictions (taken as fractile estimates) were the predicted means plus a normal variate with zero mean and variance set at the conditional variance of individual predictions. The means computed from the CDF's did not differ by more than 4 percent from the mean estimated by the original procedure, but standard deviations analogously computed differed by up to 20 percent. It appears that the estimation of variability is relatively sensitive to the excluded risk. The dominant effect of this modified estimation would be to adjust the intercept term of the equation relating variance to the controlled variables. As this intercept term does not influence the marginal risk in fertilizer use, the impact of accounting for the excluded risk would be very slight. The only clear impact would occur when the risk evaluation differential quotient depends on the variance of profits, e.g., as it does for logarithmic preference.

When experimental variability within years is large relative to between-year variability, it may, both in itself and through the estimational risk pointed to by Drynan and Lugton, have a significant impact in risk analysis and at least such impact should be carefully assessed. The notion of estimational risk is deserving of attention in other types of risk analysis such as quadratic risk programming and stochastic linear programming.

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# PROJECT SELECTION AND MACROECONOMIC OBJECTIVES: COMMENT

Basic criticisms of the McGaughey-Thorbecke article [5] left untouched by Hyslop [2] are discussed in this comment. Much of the literature on project appraisal, or Benefit-Cost Analysis (BCA), focuses upon only one step in the project cycle—project "selection." One could build a monumental library consisting solely of sources dealing with project "choice criteria." McGaughey and Thorbecke have cited a few of the more widely recognized of these. By focusing on choice criteria alone, these sources (including McGaughey and Thorbecke) implicitly assume that the problem is to select out of an infinitely large set of infinitely variable projects the sub-set which optimizes the overall planning objectives (or social objectives) of the country. Arraying these alternatives in a continuous possibilities function then allows a tangency solution with the social (or governmental) welfare function. The addition of multiple objectives does not destroy the economic principles involved, so long as weights can be developed which allow the translation of the different objectives into the traditional objective function.

The difficulty is that most developing countries are characterized by a scarcity of well prepared projects [6]. The problem is not to *choose* a project which contributes (not even necessarily in an optimal fashion) to the planning objectives, but rather to get an acceptable project brought forward for consideration. In such a context the imposition of multiobjective analysis at the appraisal stage contributes little to the process of getting a set of projects funded which even approach optimality.

The practical functions of appraisal, *per se,* are (1) to serve as a constraint to help prevent "bad" projects from getting funded and (2) to indicate needed re-design of rejected projects which can be salvaged. Under conditions of project scarcity, the weights have their greatest effect when imposed at the identification, preparation, and design stages. Ideally, the "multiobjective function" should guide project designers in putting together projects which seek to achieve the nations' planning objectives; and then, if preparation and appraisal are separate functions, it should serve as a final check to make sure at funding time that the project is economically feasible.

It is not unusual to prepare projects using multiple objectives while appraising them using conventional, single-objective "efficiency" BCA. Indeed, the World Bank and others do just that. With employment as a case in point, the World Bank still uses efficiency BCA for project appraisal, but, following the policy statements on employment laid out by Mr. McNamara in the past three years, the World Bank's projects are now more labor-intensive than was the case during the 1960's, largely because the attempt is made to prepare them that way. In this case, the objective weight on "efficiency" (which is the *only* appraisal objective) is implicit, since the conventional "efficiency" (see Marglin [4]) objective serves as a constraint.

Basically, three approaches to preparation and appraisal are possible under multiple project objectives. These are listed in descending order of preference:

1. Prepare and appraise projects based on social accounting prices and objective weights;
2. Prepare projects under social accounting prices and objective weights, but appraise them using only efficiency BCA; and
3. Prepare projects under only the efficiency objective (or, alternatively, the "engineering objective" implied in projects prepared by technicians alone—see [9 and 8]), but appraise them using multiobjective BCA.

McGaughey and Thorbecke have displayed the results from the poorest of the three alternatives.

In the cases treated by McGaughey and Thorbecke, the sensitivity testing of the objective weights was applied only at the appraisal stage. In all probability the projects were prepared under a single set of weights for the several objectives. The preparation of the set of similar projects using the same (shadow) prices and implicit objective weights should be expected to lead to relative insensitivity to shadow price and objective weight manipulations in terms of project rankings. Thus, their discussion and conclusions regarding relative insensitivity of the projects tested are wrong, or at best they are misleading. Only if they had included a wider range of project types (or had they included projects prepared to emphasize different objectives) should one expect the rankings to be sensitive to changes in objective weights.

A second criticism of McGaughey and Thorbecke's article is that their conclusion is partly correct and partly incorrect—and for different reasons than those cited:

> Thus, the use of shadow wage and exchange rates, especially with the range employed, effectively eliminates for Peruvian irrigation planners the difficult task of selecting an appropriate interest rate for discounting purposes. [5, p. 37]

The discount rate plays two roles in public investment: It allocates consumption over time, and it allocates investment capital between the public and private sectors of the economy [1]. Irrigation planners do not operate in a vacuum. Their projects are part of sub-sector, sector, and macro plans. They *should* all add up to an optimal overall allocation of capital to public investment, as well as within. Thus, irrigation planners should use project "selection" rules which contribute to overall optimality. The problem is not simply to allocate this year's irrigation budget, but rather the process should also feed

back information on how large ensuing irrigation budgets should be [7].

Their approach is relevant under the following conditions: (1) Each of the projects listed is already judged to be feasible under the relevant planning objective weights, but (2) capital rationing exists, so that all of the feasible projects cannot be funded, and (3) the levels of future government investment budgets are not effected by the comparison between the social returns from public investments relative to those from private investments. It can be argued that these three circumstances represent the normal case, which is one of the arguments for multi-objective analysis in the first place. Thus, to the extent that their statement concerning the discount rate is correct, it is not correct because of project ranking insensitivity: it is correct only because of budget insensitivity.

An additional point often unheeded in multi-objective analysis regards the manner in which the opportunity cost of capital is stated. The rational allocation of investment funds dictates that the opportunity cost of capital be stated in the same terms as the project benefits. In other words, a fundamental principle of BCA is that every objective which is included on the benefit side also be included on the cost side. McGaughey and Thorbecke do not show an opportunity cost of capital in terms of the objectives included in their weighting function, nor do they consider the possibility that the social rate of time preference might well differ between objectives [3].

It has already been said that the discussion of the opportunity cost of capital might well be moot since overall investment scope is often unaffected. However, the profusion of benefit valuation techniques which ignore their cost counterpart do little to help the selection process between projects or to improve the image of project appraisal in the eyes of those who possibly could affect the overall projects budget (most of the secondary benefit applications in the U. S. water program have shared this failing). Thus the principle of benefits and costs being measured on comparable grounds is fundamental to both problems of designing and selecting the "best" set of projects under a budgetary constraint and contributing to a change in the atmosphere in which public-private resource allocation choices are made in isolation from the relative net social returns to the two alternatives.

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# PROJECT SELECTION AND MACROECONOMIC OBJECTIVES: REPLY

Several issues raised by Ward are cogent to the problems of project design and selection, but are not crucial to the application of our proposed ranking function. He suggests (1) the ranking function applies only in the limited circumstances in which there is ". . . an infinitely large set of infinitely variable projects"; (2) the procedure and the results (especially the insensitivity of the priorities) are prejudiced by the project design procedures; and (3) the role of shadow pricing is downgraded in the procedure.

The contention that ". . . most developing countries are characterized by a scarcity of well prepared projects. . ." is primarily a statement on the quality of the prepared projects rather than on the scarcity of projects. In the case of Peru there were many projects available for implementation. The ranking function provided added information to planners—far more information than subjective policy judgments on the particular state of the projects or than on measures of their contribution to national objectives.[1]

The analysis of project designs was not developed at length in our formulation of the ranking function, but we agree with the need to apply multiple objective investment criteria in project preparation.[2] The ranking function is applicable to a variety of project preparation and selection systems including those in which projects are prepared only under efficiency criteria; in which they are designed under non-efficiency objectives (e.g., employment) with a minimum efficiency constraint; and in which weights on all objectives, including efficiency, are fully accounted for in the design.

In many developing economies, such as Peru, the project design and selection procedures—with the exception of large projects—are separate functions with the first undertaken by largely independent public institutions; national project offices intervene only at the second stage of selection. The ranking function is suited to this institutional model. As projects are designed progressively under multiple objective criteria, the function can be used to indicate project priorities. Indeed, as projects are presented for consideration which have been designed under the same objective weights as those used by national planners, they will likely be given higher priority than many designed under the efficiency criterion alone. But a practical limitation of insisting on a design using fixed weights on multiple objectives is that it is unlikely that the weights will be known beforehand. This is an argument in support of our procedure of using sensitivity analysis, especially at the final selection stage.[3]

There is a clear inconsistency in Ward's order of preference of the three approaches to project design and appraisal. One cannot disagree with the first-order choice of an integrated design and selection methodology using objective weights. Ward's second-order preference is to design projects by objective weights and determine final priorities solely by the efficiency criterion. This second approach is inappropriate for a system in which welfare weights originate from national policy makers and planners responsible for investment budget allocations—unless project designers are capable of establishing the objective weights at their level. If we accept the principle that multiple objectives (of which efficiency is one) are important, then ranking projects by the efficiency objective alone can only be justified by zero weights on the nonefficiency objectives. If the objective weights are applied at the design stage, then they are known at the selection stage, but even if they are not fixed at the design stage, they should be applied at the selection stage.

It was not recommended that Peruvian irrigation planners ignore the social discount rate forever; rather, for the projects treated, priorities were unaffected over the range of rates employed. For another set of projects or a wider range of discount rates, the project priorities may be sensitive although it should be reiterated that the projects were specifically selected to include a representative cross section that planners might be expected to consider, and the range of discount rates used was wide—6 to 15 percent. Planners may be left with the problem of selecting a social discount rate, but the possibility that a single rate would be settled upon seems unlikely. Furthermore, the view that the social time preference rate could be estimated for each objective has little relevance to actual planning situations. The mere difficulty of establishing a social time preference rate for the efficiency criterion points up the difficulty of finding time preference weights for each objective including efficiency, employment, and income redistribution.[4]

Ward establishes three necessary conditions for the application of our approach—feasibility of all projects under all objectives, capital rationing, and the independence of public and private investments. His

[1] We have discussed at length the role of project selection in our reply [3] to Hyslop [1].

[2] Significant adaptations of social benefit-cost analysis to project design are contained in the UNIDO *Guidelines* [5] and in the Little and Mirrlees *Manual* [2]. Both treat project design within a multiple objective framework.

[3] In this context the procedures recommended in the UNIDO *Guidelines* [5], involve extensive sensitivity analysis on objective weights.

[4] For example, Stewart and Streeten [4] suggest that the time preference rate for employment is less than the rate for the efficiency objective, but they give little practical guidance for their estimation.

second condition is correct. The first condition should be satisfied at the design stage as long as the concept of "feasibility" permits the selection of projects which may have a negative impact in terms of one objective and a large impact in terms of another.

As stated above, if the shadow prices and time preference rates are not known at the design stage, it is because, as national parameters, they have not yet been established at that level. If the shadow price of capital has been fixed nationally and the sector investment budget set, it can be used to value the capital costs of the projects to be ranked. If this shadow price changes and the investment budget is revised, the relative project ranking will change.

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# THE PROCESS OF AN INNOVATION CYCLE: COMMENT

In the February 1973 issue of the AJAE, Kislev and Shchori-Bachrach introduce the idea of an innovation cycle [3]. Basically, they suggest that the adoption process for technology proceeds from skilled-intensive to labor-intensive producers. They first develop a formal model of the process and then provide an empirical example. Although the paper is impressive and innovative in its own right, two aspects of it left me uneasy. These were the high degree of abstraction in the assumptions of the model and the questionable extent to which the model is demonstrated by the empirical example.

The first point is fairly obvious and can be treated quickly. The Kislev Shchori-Bachrach view of the innovation cycle gives scant attention to the many factors other than human skills involved in the innovation cycle. These would include the economic characteristics of the adopter, the nature of the technology, and the nature of the economy.[1] It also makes little or no provision for variations in the basic factors of production such as land (and climate) quality, availability of capital, and access to purchased inputs. In any given situation, innovation is influenced by a host of such variables. Skills are only one factor and may well be outweighed by many others.

The second point is less obvious and less quickly treated. It concerns the degree to which the hypothesis is demonstrated by the example cited: the adoption of low plastic row covers for growing winter vegetables in Israel. The authors base their empirical argument on differential rates of adoption of this practice among various types of farms and farming organizations. The kibbutz, and to a lesser extent the established moshav, are used to represent the skilled-intensive farms which are early adopters. Labor-intensive producers, presumably also lower in skills, are represented by the young moshav, private farms, and the Arab sector.

Skills as such are not precisely defined in the example but appear to be associated with years of schooling. Schooling is a natural starting point—it is a fairly readily available measure and would seem to have some relevance. But how confident can we be that it adequately measures the wide range of inherent and acquired human skills needed to carry out farming effectively and efficiently? Moreover, education is often a function of wealth and circumstance. Thus while the kibbutz and the established moshav may in fact be composed of the most skilled farmers, one should be careful about deducing this on the basis of schooling alone. Additional empirical measures of skill, if they could be found or developed, would be highly desirable.

Labor intensity is measured by the capital/labor ratio. The kibbutz had the highest C/L ratio; as noted above, it was also in the highest skill category. Conversely, the farms with the lowest C/L ratio, the labor intensive farms, were presumably least skill-intensive. The existence of such a dichotomy is open to some question if one looks at the data a bit more closely.

Type of farming enterprise, for example, appears to be an important factor in determining C/L ratios. While it is true that the kibbutz, as noted above, had the highest C/L ratio, it is also true that this group produced 73 percent of the winter grains, which in turn had a very high C/L ratio (70.0) [3, Table 1]. By contrast, the young moshav produced 55 percent of the vegetables which had a very low C/L ratio (2.4), while the private sector produced 44 percent of the citrus, which also had a low C/L ratio (4.5). Thus the C/L ratios would seem to be highly correlated with the type of product produced. Clearly more than type of farm organization is involved in the establishment of C/L ratios.

If one assumes that winter grains are the major crop on kibbutz farms,[2] and accepts the authors' contention that these farms are more skilled-intensive, then there is an implication—perhaps not intended[3]—that winter grains are more skilled-intensive than other crops. As one who has recently studied greenhouse food production in some detail, I find it difficult to believe that vegetable cultivation under cover requires fewer cultural skills than winter grain production [1]. Just because a crop is labor-intensive does not mean that it is not also skill-intensive. There may be, however, a difference in the number of farm workers who need to have these skills: horticulture probably requires a larger portion of hand labor for routine tasks than is true of grain production.

While vegetable cultivation under plastic covers requires more capital than is true of field production, it is undoubtedly well short of the capital investment required in mechanized grain production

[1] I reviewed these points, plus profitability, several years ago [2]. Since then there has been considerably more writing on the subject which I have made no attempt to follow in detail.

[2] This assumption may not be entirely warranted. The article does not give the relative importance of each type of enterprise in the kibbutz farm structure. But, as noted, the kibbutz did account for 73 percent of the winter grains for all types of farms. The next highest preparation was 37.4 percent for dairy, just above the proportionate share (34.1 percent) the kibbutz held of all farm production.

[3] In their text (p. 29), the authors place wheat growing in the first class of product skills: "Here experience can completely substitute previously acquired skills." This view, however, is offset by the evident importance of grains on the skill-intensive kibbutz farms.

and harvesting in Israel.[4] Mechanized equipment, in turn, requires operating and maintenance skills (and this type of skill, rather than that involved in production, may make grain production demanding in its human requirement). The older, long-established farms—the kibbutz and the old moshav—are, one might think, more likely to have accumulated the funds necessary to purchase capital goods than are the newer moshav farms. The newer farms might be less able, moreover, to afford risk. Therefore, what really may tip the scales for the older farms in the innovation cycle is a relative abundance of capital.

For these reasons, I do not find it surprising that the young moshav were initially slow in their adoption of covered vegetable production and then increased their adoption rate sharply. They may have simply needed the time to accumulate the necessary capital. Or their late adoption may have been due to factors other than skills or capital. The authors also suggest that the private sector was a latecomer (p. 35), a point that hardly seems verified by the statistics presented in Table 1.

Another part of the authors' hypothesis is that following widespread adoption of the technology, skilled producers may *exit* from the affected line of production. Again, this may be true but is not wholly shown by the data cited. All we know is that the *proportion* of covered vegetables produced on the kibbutz and the established moshav dropped between 1961/62 and 1966/67 (Table 1). We are not told what actual area changes took place in this period.[5] It is possible, for example, that the real area on the kibbutz and established moshav farms held relatively constant while a sizeable increase took place on the other farms; in this case there is no actual *exit* of skilled producers.

Finally, the author's suggestion (citing Welch) that higher rate of adoption for the latecomers was because "the variance of skills distribution is lower in these sectors, causing a speedup of the diffusion in the lower skilled groups" (p. 35) is a bit puzzling. Why should a lower variance in skills (presumably the authors refer to acquired skills) be expected to have any particular effect on diffusion? And if so, why would it be more likely to accelerate than retard the rate of diffusion?

In total, while Kislev and Shchori-Bachrach have developed a striking model of the innovation cycle, it should be realized that the model treats only one of the many factors that influence innovation adoption, and there is some question as to how well it is demonstrated by the example cited. Further attention to the empirical definition and measurement of agricultural skills and to the role of capital could enrich and broaden the usefulness of their seminal work.

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[4] Unfortunately the authors do not indicate how much the plastic covering costs per unit of area. The structures are temporary, however, and are taken down at the end of the winter season; the land is then conventionally farmed [1, p 121].

[5] Some area data are presented in Table 2 [3, p. 35], but they do not reflect change. It is, in fact, unclear what part of the 1961/62 to 1966/67 period they cover or whether they are an average. In any case, they total 1,029 ha. or 2,543 acres. Other data for 1969/70 suggest a total vegetable area of 2,200 ha. or 5,440 acres [1, p. 121].

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# THE PROCESS OF AN INNOVATION CYCLE: REPLY

Our article is a suggested theory of a certain type of innovation diffusion process. As a theory, it focuses on the crucial aspects of the process and abstracts from others. The real world is more complicated than our theoretical structures and loaded with disturbances. Thus, for example, we cannot report in our tables exit of higher skilled growers—as the model predicts—because orderly data collection started in the winter of 1958/59, several years after the introduction of the innovation, and the available statistics fail to reflect exit of early adopters. We know, though, of several kibbutzim which adopted the innovation in the early days for only two or three growing seasons. Also, the median year of schooling is higher in the kibbutzim than in the other sectors, but intrasectorial deviations exist, and some kibbutzim continue to grow plastic covered vegetables more than others.

More crucial is Dalrymple's point that innovativeness may be associated with capital labor ratio and with farm type and not with skills. In a competitive economy,[1] farm types and capital labor ratios are not exogenous, as Dalrymple seems to imply, but rather to a large extent endogenous. Because of complementarity between schooling (our most important measure of skills) and other factors, more schooled farmers will be more capital intensive; and since there is often a single dominant technology in the production of a certain product (an exception being dairy in our Table 1), capital labor ratio is increased by changing the combination of activities—modifying the farm type. This is the point stressed in our Table 1.[2] The higher implicit labor cost (shadow price) of the schooled farmer is augmented by his ability to manage a more capital intensive enterprise. His allocative skills are reflected in his choice of farm type and scale; and his rent to these skills is increased when circumstances change and require fast adjustment.

In our model the innovation moves from one skill to another. If, in the process, a completely homogenous sector is reached, all farmers in this sector should, by the model, adopt the innovation simultaneously. This is why a lower variance in skills is associated with higher rates of adoption.

I read Dalrymple's "Comment" as a call for further and better work in the field of the economics of information and technical change. We see such work being done now in several places. So long as we theorize, however, we should not expect to find in the real world exact duplications of our models. Abstraction is the weakness and the strength of theory.

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[1] Israel's agriculture is not strictly competitive, but despite Government intervention, it reflects many of the characteristics of a competitive industry.

[2] Kibbutzim do not specialize in field crops. For reasons of diversification and complementarity of products, they operate many activities. They tend, however, to operate larger proportions of capital intensive lines than the other sectors.

# COSTS AND RETURNS OF EDUCATION IN FIVE AGRICULTURAL AREAS OF EASTERN BRAZIL: COMMENT

Patrick and Kehrberg's [7] findings on costs and returns to education in five agricultural areas of eastern Brazil appear to undermine popular conceptions about the contribution of education to productivity (be it agricultural or nonagricultural). According to the authors, the unique feature of their inquiry is its "micro-focus" on the education:productivity relationship, in areas which are distinctly agricultural. Reference is made to the inadequacy of largely "macro-analytic" studies attesting to positive effects of education in the growth process as data typically relate to non-agricultural economies or agricultural sectors of developed economies. As an example of the concensus of such studies, consider the following;

(1) Quantitatively, it has been demonstrated that population and labor force education is a key element in growth of productivity (Jorgenson and Griliches [5]; Denison [1, 2]; Easterlin [3]; and Galenson and Pyatt [4]). Easterlin found that the very countries which acquired British technology first in the 19th century all had higher levels of schooling than Great Britain at that time.

(2) Galenson and Pyatt [4] found that increasing education was approximately 11 times as effective as increasing investment in productivity growth in less developed countries (LDC's). Higher education was second only to nutrition in labor productivity increases.

(3) A leading criterion of Kuznets' [6] definition of "modern economic growth" is the application of modern scientific thought and technology to industry, transportation, and agriculture as a means to rapid and sustained growth in GNP.

(4) Schuman, Inkles, and Smith [8] found that in changing social contexts, the more educated and literate are quicker in perceiving change and will find it easier to redefine their beliefs in ways that fit their new needs and interests.

With respect to policy formulation, implications of the studies above are relatively straightforward; investment in education will stimulate increases in individual and collective productivity due to improved "worker and allocative" effects, etc. That Patrick and Kehrberg suggest this may not be a viable economic tool is an extremely important contention.

This comment proposes that Patrick and Kehrberg's empirical model may lack explanatory import and thus may be a weak instrument for policy guidelines. Four issues are discussed in support of this claim.

First, it is one thing to suggest that costs and returns to education are low or negative in context $X_i$; it is quite another to suggest the same for all $X$. Now, consider the possibility that the five study areas are bound by the "*minifundio-latifundio* and landless employee" complex. This would imply the following [see 9, Ch. 2 and Table 3]:

(1) The structure of land tenure is institutionally rigid and the distribution of income unequal.

(2) The land tenure system, credit possibilities, pricing, and marketing arrangements impede possibilities of higher incomes on *minifundios* (i.e., due largely to *latifundismo* exploitation).

(3) Land tenure rights for the landless employee/tenant class are unstable, and this has a direct bearing on realized profits and motivation (i.e., *latifundistas* typically exploit their resident employees).

(4) *Latifundistas* typically operate their farms back from a profit maximizing point on their production possibility curves.

(5) Land is seldom farmed intensively on *latifundistas*.

(6) A large proportion of *latifundistas* can be characterized as absentee landlords.

(7) *Latifundistas* invest very small proportions of their profits into their farms.

If the conditions above apply to Patrick and Kehrberg's samples, we would expect the potential contribution of education to productivity to be shackled. We could also attribute low correlations, for example, between *latifundismo* education and productivity to absentee landlordism. Data in Table 1 indicate that the "*minifundio-latifundo*" complex is in evidence in the three Brazilian states represented in the study. Also, the singular importance of the fixed capital variable (FC) in Patrick and Kehrberg's Table 1 could be interpreted to mean that without presence of wealth necessary to purchase FC, education could be rendered inoperable as either an FC or productivity generating input.

Unless the "*minifundio-latifundio*" complex can be realistically assumed away, it would seem that a more appropriate inference for policy is that "educational investment in Latin American agriculture is not likely to result in appreciable gains to individual or collective productivity unless the institutional context is modified." Possibly the greatest return to education over time $t$ is its indirect and immeasurable effects which may manifest themselves in critical institutional reforms at time $t + n$ (e.g., aggressive land redistribution). In turn, rapid productivity gains to education may be observed at time $t + n + y$ due to unmeasurables at $t$ and lagged effects at $t + n$. As for Patrick and Kehrberg's view that out-migration of the educated may have benefits, this is questionable on the grounds that the rural "poverty:elite status quo" will be maintained, and serious problems of urban unemployment and under-

Table 1. *Latifundismo* in three Brazilian states, 1960

| | Latifundios | |
|---|---|---|
| Geographical Entity | Percent Farms >200 Hectares | Percent Total Agricultural Land on Farms >200 Hectares |
| Brazil | 5.3 | 35.8 |
| Region of Leste | 6.0 | 41.8 |
| State of Minas Gerais | 9.5 | 45.3 |
| State of Espirito Santo | 3.2 | 23.6 |
| State of Rio de Janeiro | 5.5 | 45.5 |

Source: *Censo Agricola De 1960,* Vol. II, Pt. I, Brazil.

employment are already in evidence in most Latin American cities (see Shaw [9]).

A second problem pertains to a likely bias in Patrick and Kehrberg's parameter estimates of the distribution of education and value added. The bias arises because crucial variables such as "ability" and "social status" were omitted from their model.

A third problem concerns the number of observations which were assigned a zero for "no education" *vis-à-vis* the range and distribution of those with education. If a large share of the sample population has no or little education, this will obscure the incremental effect of those who do. If the population is largely homogeneous, this will also account for the low $R^2$. It would be interesting to see results of the regressions with the "zero observations" removed.

A final question is policy-related in its concern with the type of education available to Latin American farm operators. A major criticism of education systems in less developed countries is that emphasis is placed on classical versus applied education. Accordingly, arguments that returns to costly education are low should be qualified as to the educational content and its compatibility with applied labor force activity.

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# COSTS AND RETURNS OF EDUCATION IN FIVE AGRICULTURAL AREAS OF EASTERN BRAZIL: REPLY

Economics of education literature is nearly unanimous with respect to the payoff of schooling in the overall development process. However, the objectives of our study [2] were more limited: How much do individual commercial farmers benefit in monetary terms from education (schooling and extension) in the areas studied, and does education have a favorable benefit-cost ratio at this level? Since only increased value-added in production accruing to the individual was considered with other private and social educational benefits excluded, the return used in the analysis is essentially a lower bound estimate of educational returns.

Shaw [4] suggests the contribution of education in the areas studied may be reduced by existence of a *"latifundio-minifundio"* complex. Although the hypothesized implications of a *"latifundio-minifundio"* complex might reduce the returns to education, it is unlikely to have done so in this study. The areas included in the study are not ones which typify the *"latifundio-minifundio"* complex. Conceição de Castelo and Viçosa are areas which have large numbers of small farms, but farms of less than five hectares were not included in the sample. In Paracutu and Alto São Francisco, areas of more extensive agriculture, farms of less than 10 hectares were excluded, and in Resende only farms with more than five dairy cows were considered. Exclusion of the very small farms in all areas and tenants, except in Conceição de Castelo, eliminated those situations for which the lack of resources might be expected to be a major limitation.

As noted in the original article, complementarity between investments in educational activities and other public investments was not considered. Similarly, the future returns to education resulting from educationally induced institutional modifications (e.g., increased agricultural research or land redistribution) were not considered. Welch [5] has shown that eliminating agricultural research would reduce the wage differential among schooling levels in U. S. agriculture by about one-third. The tendency for the returns to schooling to increase with the level of agricultural modernization observed in our study and the one by Haller [1] suggests the complementarity between education and research may be even higher in developing countries.

The second point raised by Shaw, that of possible bias in the parameter estimates because of excluded variables, is correct. Ideally, variables such as "ability," "social status," and possibly others should be included, but data are unavailable. Years of schooling completed and number of extension contacts act as proxies for the excluded variables as well as the "true" input of the educational activities in agricultural production. It is hypothesized that "ability" and particularly "social status," given the relatively high costs of schooling borne by the individual, would be positively correlated with the years of school completed. Extensionists have attempted to select the better farmers and community leaders with whom to work, suggesting a positive correlation between the excluded variables and number of extension contacts. As long as the excluded variables have positive effects and the correlations between excluded and educational variables are not negative, the estimated parameters would tend to overstate rather than underestimate returns to education in this study.

A high proportion of farmers in the samples, from 19 percent in Resende to 52 percent in Alto São Francisco, had no formal schooling. In reducing the length of the article, the results obtained when excluding farmers with no schooling and/or extension contacts were left out. Excluding the zero level observations had only marginal effects on the size or significance of the parameter estimates in all of the areas studied and did not change the conclusions.

We fully agree with Shaw in his concern with the type of schooling available. As noted in the article, the educational system is undergoing substantial change, but has had a very classical orientation. Modifications in the educational system to increase its relevance to labor force activity may raise future returns, but as long as agriculture remains traditional, farmers as individuals will have little or no economic incentive to invest in schooling. Although "schooling *per se* cannot bring about the transformation of traditional agriculture" [3], this does not deny the importance and probable payoff of schooling and extension when placed in an appropriate combination with other factors.

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# A MORE GENERAL DEFINITION OF THE ECONOMIC REGION OF PRODUCTION, PERMITTING VARIABLE INPUT AND PRODUCT PRICES*

In their very interesting 1969 paper, Seagraves and Pasour [7] clarified several issues and problems related to defining the economic region of production and stimulated further contributions on this subject [5, 6]. Although possible effects of variable prices upon the economic region of the production function were mentioned by both Seagraves and Pasour [7] and by Gates [5], they did not propose a formal definition of the precise economic region for the case of variable product and/or variable input prices.

While a student in a production economics course, the junior author extended the definition of the economic region of the production function to include the case of a variable product price for the Cobb-Douglas production function.[1] Desiring further generality, the senior author attempted to extend Anderson's results for the Cobb-Douglas and discovered that it was possible for some price and production functions (not necessarily homogeneous) to define the economic region in terms of the elasticity of production (function coefficient) and the product and input price flexibilities.

Johnston and Nelson [6] have suggested that the traditional discussion of "stages of production" should either be dropped or amended to include explicit specifications on the nature of the production function and factor fixity, and the nature of product and factor price relationships [6, p. 109]. We think that treatment of the stages of production should be retained. The simple case with fixed prices is interesting and instructional, especially for seeing relationships between total, average, and marginal products at key points. However, the earlier discussion [5, 6, 7], showing that the traditional textbook treatment is a special case, is a good theoretical point and demonstrates the need for a more general formulation.

Thus, it is our purpose to present a more general delineation of the relevant (economic) region. Before doing so, it is necessary to specify clearly the properties of the production function, as noted by Johnston and Nelson [6], and to specify what we mean by the "economic region of production." We will consider the relevant economic region of production to be that subset of the input and product space wherein the unconstrained maximum of the profit function must fall. Of course, there are many possible functions where no unconstrained profit maximum can be obtained, such as for any homogeneous production function with elasticity greater than one, when prices are fixed. In such cases, by the above definition, there would be no relevant economic region of production.

We will assume, following Ferguson [4, p. 60], that the production function is single valued, continuous, and otherwise well defined over the range of inputs yielding non-negative outputs. Further, continuous first and second partial derivatives are assumed for the production function, and the inputs are real variables defined over the non-negative domain of real numbers. From the preceding properties, any "fixed factors" would affect our assumed production function only indirectly and would not be included as explicit variables in the production function. (This interpretation also agrees with Carlson's [2, p. 14].) Thus, the above properties imply that any fixed inputs have already been committed and must be fully used to the extent implied by the production function for the variable inputs. Admittedly, it is possible to define a production function differently and to include the effect of a fixed factor directly in the production function [6, 7]. However, so-called "divisible fixed" factors [6, p. 111] require a definition of production function with different properties than those listed above from Ferguson [4, p. 60].[2]

Given the preceding definition of the production function in terms of variable inputs only, as taken from Ferguson [4, p. 60], no particular difficulty in defining the economic region of the production function should be encountered for the simplest case of fixed input and product price [2, pp. 21–23]. However, the case with variable input and/or product prices is obviously more challenging.

## The General Case

Before attempting to derive the general result, we first consider the class of production functions which

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[1] Originally this special case was derived by inspecting the second order conditions for a maximum of the profit function. However, because of the reviewers' recommendation and space limitations, Dr. Anderson's treatment of the Cobb-Douglas case was deleted. Nevertheless, many readers could benefit from working through the analysis for the Cobb-Douglas case.

[2] The preceding discussion is not meant to imply that our assumed properties of the production function are realistic for many real life situations. Any one definition of the production function for theoretical purposes may well be inappropriate for many actual economic problems. For example, the usual factor-factor and factor-product relationships of traditional static production economics are often inappropriate when time is considered, as noted as early as 1958 [1]. (A clear and comprehensive treatment of the problems involved in profit maximization over time is given by Dillon [3, pp. 66–102].)

possess the property of having a constant marginal rate of technical substitution for movements along a ray from the origin. (As is well known, homogeneous functions possess this property since their partial derivatives are functions only of the input ratios.) Suppose further that the production function *and* input price functions are such that the inputs are in constant proportions along the expansion path (a straight line from the origin for the two-variable input case). Denote this hypothesized property of the production *and* input price functions as the "scale line expansion path" property. For production and input price functions satisfying this property, the lower bound of the economic region of production can be defined with the aid of the following theorem:

> If there exist production and input price functions such that the expansion path is always a scale line and, also, if the production and price functions are such that the ratio of total value product to total variable cost is a function possessing a continuous first derivative with respect to a composite input variable, $X_i$, and the ratio decreases steadily without tending to some limit $\theta > 1.0$ for all values of the composite input variable, $X_i > X_i^0$, then a maximum of the profit function is assured (or no output is profitable), and the elasticity of production, $\epsilon$, will always be less than one plus the composite input price flexibility, $\lambda_c$, (from the composite cost function) divided by one plus the product price flexibility, $\lambda_q$. That is, it must be that $\epsilon < \dfrac{(1+\lambda_c)}{(1+\lambda_q)}$.

*Proof:* Decreasing ratio of total value product to total variable cost for $X_i > X_i^0$ implies that the first derivative of this ratio is negative. (For convenience, let $X_i = X_1$.) Then, express $q = f\ (X_1, X_2, \ldots, X_n)$ as $q = g\ (X_1)$, since we have a scale line expansion path. Similarly, product price, $p$, is $p = p(q) = p\ [g\ (X_1)]$, and total variable cost,

$$TVC = \sum_{i=1}^{n} p_i X_i = X_1\phi(X_1), \text{ which we can write}$$

as $TVC = X_1\phi$. Also, $TVP = pq = p[g(X_1)] \cdot g(X_1)$. Thus,

$$\frac{d\left(\dfrac{TVP}{TVC}\right)}{dX_1} = \frac{d\left(\dfrac{pq}{X_1\phi}\right)}{dX_1}$$

$$(1) \qquad = \frac{X_1\phi\left[\dfrac{dp}{dq}\dfrac{dq}{dX_1}q + \dfrac{dq}{dX_1}p\right]}{(X_1\phi)^2} \frac{-pq\left[\phi + \dfrac{d\phi}{dX_1}X_1\right]}{(X_1\phi)^2} < 0.$$

Multiplying both sides by positive $(X_1\phi)^2$, dividing both sides of the inequality by $p$, $\phi$, and $q$, and rearranging terms, we obtain

$$(2) \qquad \frac{dq}{dX_1}\frac{X_1}{q}\left(\frac{dp}{dq}\frac{q}{p} + 1\right) - \left(1 + \frac{d\phi}{dX_1}\frac{X_1}{\phi}\right) < 0,$$

or $\epsilon(1+\lambda_q) < (1+\lambda_c)$. Q.E.D.

Before discussing the implication of the result, a contrived example can illustrate that it is possible to meet the conditions of the theorem. Suppose we had a Cobb-Douglas production function $q = A X_1^{\alpha} X_2^{\beta}$, and input prices $p_1 = K_1 X_1^{\gamma}$ and $p_2 = K_2 X_2^{\gamma}$. The reader may verify that, in this case of equal input price flexibility, the expansion path remains a scale line, just as for the case with constant prices. Other examples can also be contrived, using other algebraic forms of the product and input price functions, e.g., any homogeneous production function and input price functions with equal price flexibilities will give scale line expansion paths.[3]

In some cases factor prices can be regarded as approximately constant. For these cases, the less restrictive property of a production function with scale line isoclines can be substituted for the scale line expansion path requirement. Then the result of (2) reduces to $\epsilon < 1/(1+\lambda_q)$.

When both product and input prices are fixed, the result of (2) reduces to $\epsilon < 1.0$, as it should. In any case, (2) corresponds to the beginning of the "economic region of the production function." If one argues that input prices would usually be an increasing or constant function of their levels, then in (2), $\lambda_c \geqslant 0$. Similarly, for product price constant or diminishing [2, p. 31], $-1 < \lambda_q \leqslant 0$. Under these assumptions, the boundary marking the end of the economic region would be the usual result, $\epsilon = 0$. Thus, production would be expected to occur in the range $0 < \epsilon < (1+\lambda_c)/(1+\lambda_q)$. According to this result, the economic region could extend considerably into the area where $\epsilon > 1.0$ for variable prices when $\lambda_c > 0$ and $\lambda_q < 0$. It should be noted that this interpretation of possible production where $\epsilon > 1.0$ follows from our definition of the production function and implies that one or more fixed inputs have not only been paid for, but must also be fully *used*, as noted by Johnston and Nelson [6]. Otherwise, it would pay to reduce the amount employed of the fixed factor and thereby obtain a greater amount of product per unit of variable factor. However, we preclude such a situation, since only variable factors are permitted in our definition of production function as discussed earlier.

[3] In fact, combinations of input price functions which have equal price flexibilities with any production function possessing scale isoclines will have the desired property. One example would be the non-homogeneous production function, $q = A_1 X_1^{\alpha} X_2^{\beta} - A_2(X_1^{\alpha} X_2^{\beta})^{\gamma}$, where $A_1, A_2 > 0$, and $\gamma > 1.0$.

It is also possible to obtain the result given in (2) by using the traditional cost relationships, as presented by Carlson [2] and extended somewhat by Ferguson [4, pp. 178–179]. By rewriting Ferguson's Equation (8.3.19) and using some of the same definitions of our earlier theorem, we obtained exactly the same result given by (2). However, this analysis is omitted here to conserve space.

## Conclusions and Limitations

If the variable inputs are not varied in constant proportions, the relevant economic region of production cannot be related to the elasticity of production and the input and product price flexibilities, even though the first form of the equation in (2) would still define the beginning of the relevant economic region of production. That is, if the inputs are not in constant proportions along the expansion path, some other meaning and symbol would have to be attached to $\frac{dq}{dX_1}\frac{X_1}{q}$.

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*Reviews are listed alphabetically by authors.*

# Book Reviews

Aaron, Henry J., *Shelter and Subsidies: Who Benefits from Federal Housing Policies?* Washington, D. C., The Brookings Institution, 1972, xiv + 238 pp. ($7.95)

Downs, Anthony, *Federal Housing Subsidies: How Are They Working?* Lexington, D. C. Heath and Company, 1973, xv + 141 pp. ($9.50)

These two books on Federal intervention in the U. S. housing market are complementary in spirit. They are addressed to the same question—what does Washington get for its expenditures on housing? They both approach the issue by taking up one program at a time, and neither attempts a long-range, econometric-type assessment of the role of government in housing. They are both partisan, in a sense to be explained below, and it would probably not surprise or displease either author if the tone of both books were described as carping. Both authors have access to special and important data, and both make good use of it.

Henry J. Aaron is a senior fellow in The Brookings Institution. His article on "Income Taxes and Housing" in the December 1970 issue of *The American Economic Review* is clearly a parent of the 1972 book; that article, in substantially the same form, is the central chapter of *Shelter and Subsidies*. The book goes beyond income tax aspects of Federal housing programs, however, into mortgage credit programs and public housing.

There seems to be something about housing that makes policy analyses turn quizzical. Almost at the outset, Aaron admits that the reasons for having a Federal housing policy at all are "extremely vague" (page 21). He next discounts the gamut of statistical information we all rely on to discuss housing issues because "the numbers tell a confusing story" (page 23). From that point he concentrates on exposing what he takes to be unintended subsidies of housing.

First comes the income tax provisions he wrote about in his earlier article. Aaron estimates that the deductibility of mortgage interest and property taxes was worth about three billion dollars to homeowners in 1966 and that the exclusion of inputed rent on owner-occupied dwellings cost the Federal government four billion dollars more. Rental housing also benefits from depreciation allowances, but no money estimate is provided. Aaron calculates reductions in rent that depreciation provisions could permit, given a competitive rental market. Despite the major statistical investigation on which it is based—90,000 individual tax returns made available to Brookings—this study is uneven and inconclusive. The "effects" of tax benefits for housing are demonstrated only by hypothetical illustrations. Deductibility of property taxes and interest on rental property are simply ignored, as though a case against homeownership were being fabricated.

Aaron finds an element of subsidy in the FHA mortgage insurance program, despite 1970 receipts of $317 million against expenses of $70 million. Since the probability of default losses is greater for low-income borrowers while everyone pays the same premium rate, the effect is a transfer from higher income borrowers to those with less income. Aaron acknowledges, though, that mortgage insurance has produced major and immeasurable benefit by simply improving the workings of the mortgage market. Much the same is said about credit institutions such as FNMA, GNMA, and the Home Loan Bank Board. Aaron notes the scale of Farmers Home Administration programs—five billion dollars in loans and grants from 1967 to 1972—and the fact that over 90 percent of the housing loans by this agency are made to middle-income families in small towns, not to farmers. He very tersely tells the history of public housing and major housing assistance programs such as Section 221 d3.

In his concluding chapter Aaron describes the housing strategy of the United States as subsidized filtering—encouragement, primarily through tax provisions, of improved housing standards for middle- and upper-income families. While he faults this strategy on equity, he concedes that the alternative of subsidizing the construction of new housing for low-income families carries a higher per unit price tag, about $1,600 per year or 50 percent above the price of adequate existing housing. Finally, he pre-

sents elaborate estimates of how a "housing assistance plan"—cash grants to qualified families—might work. His predictions are clouded by uncertainty about the housing supply response to this increase in effective demand.

The book by Anthony Downs portrays a scheme of trade-offs between principal housing strategies or tools—e.g., low-income public housing or Section 235 subsidies—and the principal objectives of Federal housing efforts over the years—e.g., rehousing the poor in the central city versus dispersing them through suburbia. It is a much more conceptual approach than the Aaron book and self-consciously assumes responsibility for choosing which kinds of housing programs are best for the United States, or at least for narrowing the choice. The book culminates in a fold-out, two-color "Grand Strategy Matrix," with 49 squares representing combinations of generalized objectives and relatively pure forms of programs. Many of the squares carry notes explaining their non-feasibility. One square has a star, indicating "Real Estate Research Corporation Preference." Mr. Downs is Chairman of Real Estate Research Corporation, and the corporation, with support from The National Association of Home Builders, The United States Savings and Loan League, and the National Association of Mutual Savings Banks, funded this effort.

Mr. Downs has the background and the insight to justify his abstract, subjective approach to the housing subsidy question. He assumes the information which the Aaron book, among many others, discovers. He is probably as conversant with actual workings of specific Federal housing programs as anyone not in government. In running through these various programs, he classifies and judges them rather than describing them. His assertions are supported with numerical information only in a few cases, evidently those in which he believes significant data has not previously been brought to light. For example, default rates for major FHA mortgage insurance categories are presented and discussed. On the other hand, his explanation of what went wrong with Section 235 is a list of "valid or partly valid criticisms." In other words, Downs is performing the role of judge, not that of a researcher. It would be important to the reader to know that Downs has fair claim to competence as a judge.

That does not mean his rankings, evaluations, and identification of critical factors connected with housing policy and programs have to be accepted. They amount to a thoughtful outline of the housing question in the United States, phrases and categories fully as useful to public discussion as statistical analysis or economic theory.

Like Aaron, Downs believes that the major thrust of U. S. housing programs is subsidized filtering, or as Downs puts it, to "flood the market" and keep housing prices relatively low, and to do this primarily—if unintentionally, perhaps—through income tax provisions. More explicitly than Aaron, Downs distrusts this filtering strategy, and offers his own recipe. Like Aaron, Downs is not really sure why there has to be a Federal role in housing, or if there is one how large it should be. "Not everyone legally entitled to a subsidy really needs it," he states (page 69).

Both Aaron and Downs feel that what the Federal government is actually doing about housing is inappropriate, that we do not know what we are doing and we do not know what we want done. Both are honest enough and sufficiently informed to be very tentative about what we should do. Housing is a bundle of things, after all, and it is involved delicately in the whole national metabolism. There are dimensions to the effects of policy and to the judgment of aims that our forms of analysis, let alone our data, cannot handle. Criticism cannot be constructive just yet, except in the sense that it gets us to look more closely at ourselves. In one of his concluding sections Downs breaks the seal on our envelope of self-doubts when he says: "The most crucial single improvement in urban affairs would be effective local surveillance . . . [and that] requires radical reform in the system of criminal justice, which simply does not work in [deteriorating central city] areas" (page 118). So much for the closing of tax loopholes.

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**Berthold, Theodor, *Die Agrarpreispolitik der DDR: Ziele, Mittel, Wirkungen*, Berlin, Duncker & Humblot, 1972, 295 pp. (DM 45.00)**

In rigorously organized arrangement, the author presents the subject matter of East German agricultural price policy in five chapters. They deal consecutively with (1) the theoretical foundations, (2) the basic tools, (3) a historic overview by commodities, (4) the relationship of agricultural prices with those for agricultural production factors and for the food wholesale and retail sectors, and (5) a critical evaluation.

Soviet Military Government fixation of agricultural prices began with and generally continued the prices set by the Nazis in 1944, the last marketing year of the war. Whereas the Nazis compelled farmers to deliver the entire marketable production of their crops and livestock to designated governmental agencies, the Soviet compulsory delivery system pertained to specific quotas, for which "Erfassungspreise (collecting prices)" were paid. Overquota sales fetched much higher "Aufkaufpreise (purchase prices)." The typically wide divergence between these two types of prices brought about wide variations in average prices or unit values received by farmers. The author points out that in a market economy the marginal price tends to decline with increasing production, whereas under the pricing policy prevailing in the DDR until the 1960's, the

marginal price was much higher than the average price. This programmatic price variation was used to help in the collectivization of East German agriculture by setting the compulsory delivery quotas for large farmers so high as to leave little or no room for high-priced overquota sales. For the smaller East German farmers, this Soviet-type, dichotomous marketing and pricing system may have had libertarian aspects, compared with the Nazi system. The two-price system was also used to compel the delivery of the quantities of crops, particularly grains and potatoes, which the government wanted delivered. In general livestock and livestock product prices were so attractive that overquota supplies of grains and potatoes were fed. Thus, overquota sales of crops were relatively unimportant, whereas such sales of livestock and livestock products were of great supply and price significance. Measured in "grain units," livestock and products accounted for three quarters of agricultural production in the DDR in 1968, while crop products made up only one quarter.

In 1962 the two-price system was abolished for potatoes, and uniform producer prices were introduced. In fulfillment of an Ulbricht postulate announced in 1963, grains, sugar beets, and oilseeds followed in 1964, and in 1969, livestock and products were subjected to uniform pricing. With the introduction of uniform prices, the compulsory delivery quotas were abolished. The new uniform producer prices are basis prices. They may be enhanced when (collective) producers negotiate premiums with their buyers, typically in connection with supply contracts specifying quantity, time, and quality of goods to be delivered. However, premiums for increases in the production of livestock and products were also introduced and these were regionally varied, with larger premiums being paid in the North than in the South.

In light of European Community beef-milk imbalances, the book's sections on beef and milk pricing make fascinating reading, although the data presented are neither intended for a comparison between the DDR and EC beef and dairy economies nor do they permit a direct comparison. Beef production grew significantly from 1963 to 1968; but the experience with the uniform price system prevailing since 1969 is not evaluated.

The bibliography enumerates a large literature on the subject, originating in both parts of divided Germany.

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**Galbraith, John Kenneth, *Economics and the Public Purpose*, Boston, Houghton Mifflin Company, 1973, xvi + 334 pp. ($10.00.)**

The book divides into five parts. Part One, *The Forest*, sketches the terrain. Here two chapters are devoted to a rather conventional summary and critique of neoclassical economics. Within this framework the role of the state, orginally conceived as limited, has gradually and grudgingly been allowed additional importance in the realm of monetary and fiscal policy. But as to the nature of technical progress, the view remains that this process is essentially random (p. 26).

In a chapter on *The Use of An Economic System*, the author tells us trenchantly: "Perhaps the oldest and certainly the wisest strategy for the exercise of power is to deny that it is possessed" (p. 5). But the quality of these insights is highly uneven. Witness the following observation: "There is little doubt that revolutions tend to break out in the United States at the point in history when they have become comparatively safe" (p. 9). Any student of the American Revolution, the Civil War, and the truly remarkable amount of violence in American history—of both the successful and aborted variety—will be amazed by this simplistic view.

In a chapter devoted to the household, Galbraith deplores the crypto-servile status of the American housewife. However, perhaps because of Galbraith's historical view of revolutions, he never raises the battle cry: Housewives of the world unite, you have nothing to lose but your husbands!

The final chapter in *The Forest* deals with the "planning system"—a loose synonym for the oligopolistic sector—its pricing policy and relationship with competitive markets, its technological progress and symbiotic relation with government. Many of the parts of *The Forest* are revisited subsequently for more detailed exploration. In fact at the end of the journey this reviewer felt that he had not seen enough daylight.

Part Two contains a rather short elaboration on the market sector (pp. 55–77). Much emphasis is given to the "social virtue of self-exploitation" of the small businessman in form of long hours and very intense work.

Part Three represents a substantially longer section of over 80 pages on the *Planning System*. This is essentially a cataloging of the sins and virtues of the large corporations. Since most of this has been discussed by Galbraith and others before, it lacks the sex appeal frequently found in "sin and virtue" discussions. The only topic here which is new is a discussion of the transnational firm.

Part Four, extending over approximately 20 pages, explores the undesirable economic and broader social consequences of the two systems interacting upon each other with unequal strength.

The final section—*A General Theory of Reform*—of 100 pages is given to a critique of current taxation, anti-trust, environmental-, and monetary policies, to name just a few. What is advocated instead is comprehensive planning with permanent controls in the concentrated sector and fiscal rather than monetary policy for stabilizing aggregate demand in order to assure fulfillment of public purposes. We are never

told clearly what the "planning system" embraces other than it is made up of ". . . a few thousand of the largest firms" (p. 313).

Galbraith may rightly question how well we are served by standard theory with its methodology of heroic abstractions, but what he purports to counterpose as more empirical, historical approach is frequently nothing more than grandiose caricatures of historical phenomena which serve us even less than the abstract theory.

Numerous of Galbraith's pseudo-historical generalizations were already developed in his earlier books. But in spite of earlier criticisms of the excessively broad brush strokes, the same sketches are once more presented without any refinement. So we are told that appearance of the modern union is associated with the rise of the concentrated planning system (pp. 188, 189). It is stated that ". . . in much of the market system they [unions] do not exist" (p. 186). Jimmy Hoffa would probably be pleased by this rendition. It is only grudgingly admitted that occasionally in competitive industries—such as the clothing and construction trades—small businessmen deal with a few strong unions (p. 186).

Elementary knowledge of American labor history tells quite a different story. The nucleus of the old A F of L prior to the New Deal was the so-called aristocracy of labor such as the construction trades, needle trades, machinists, typographers, cigar makers, and teamsters. In concentrated industries such as steel and automobiles, early labor unions had been virtually exterminated by the twenties to reappear only with the assist of the New Deal in the thirties. This also calls into question the earlier cited cliche about "safe revolution." The argument, of course, could be salvaged by a definitional trick, namely reserving the term revolution only for those attempts of drastic change which turn out to be successful.

Again, we are told the planning system needs its pricing policy, because—among other things—". . . the production period, the time that elapses between a decision to produce and the emergence of the product, is much longer than in the market system" (p. 113). It takes at least 30 years to produce a stand of timber and approximately six years for an orchard to yield anything at all. These are sufficiently long time spans to produce several generations of computers.

We are told that the crypto-servile role of women in the household is "critical for the expansion of consumption in the modern household" (pp. 33, 58). Whatever the true explanation for whatever exploitation of women takes place, however defined, it must be apparent that Galbraith's is off the mark. Can there really be any doubt what the corporate giants desire about housewive's labor market decisions? Of course not: "Go to work, buy another car and at least six new dresses to make yourself look respectable on the new job! For your labor in the home we can substitute many gadgets." Besides, "theory" suggests to this reviewer that business may also have good reasons to favor an increase in the supply of labor as this is supposed to lower the wage level.

As already mentioned, the general picture of the market system as compared to the planning system is one of technological backwardness, low incomes, which even at such levels can only be sustained by the willing "self-exploitation" of small businessmen. Again, this overdrawn picture of medieval artisans is not very helpful.

Contrary to Galbraith, in recent years a very high proportion of new large fortunes were actually generated in the market sector, e.g., Kenneth Wilson (Holiday Inn), Colonel Sanders (Kentucky Fried Chicken), Ross Perot (computer services), and Leonard N. Stern (Hartz Mountain, pets, pet foods and accessories). Other fortunes above $50 million [1] were made from such mundane activities as cut-rate insurance, drug chains, and trailers.

Admittedly, conventional theory does not help us very much in an understanding of how an individual can amass a huge fortune on nothing more than a fried chicken recipe or pet foods and flea collars. Perhaps the short-run disequilibrium lasts much longer than our shorthand classroom presentations seem to suggest. Perhaps this also explains why economists, in spite of some expertise and contrary to the layman's image, do not appear spectacularly successful in making great fortunes: people with the credo that all buyers and sellers are continuously so well informed as to cause prices to hover at all times close to the equilibrium are not apt to be very sucessful bargain hunters. However, while neoclassical theory may not be very helpful in explaining the rise of these large fortunes in the market sector, Galbraith goes one further and ignores their existence. But let us leave the super rich. In experiences with the plumber, garage, and routine pilgrimages to repair shops to pick up appliances, this reviewer was never able to observe the self-exploitation of these craftsmen, which Galbraith so vividly describes.

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## Reference

[1] Louis, Arthur M., "The New Rich of the Seventies," *Fortune* 88:170–175, 230–242, Sept. 1973.

**Gossling, W. F., *Productivity Trends in a Sectoral Macro-Economic Model: A Study of American Agriculture and Supporting Industries 1919–1964*, London, Frank Cass and Company, 1972, xxii + 296 pp. (£7.50)**

The principal thrust of this short monograph is to define and measure changes in "gross output subsystems" for agriculture. After measurement and

comparison of productivity indices related to the sub-system for U. S. Agriculture, an application using sub-system productivity indices as variables in macro-economic analysis of American agriculture is presented. The text is 164 pages divided into seven chapters liberally supplemented with 22 tables and 24 figures. Appendices equal chapters in number comprising 124 pages; two appendices present mathematical extension of material presented in the text, and the other five provide supportive data and results including 37 tables.

Since the analysis revolves around the "gross output sub-system," perhaps a definition and a comment are first in order. In Gossling's words consider an economy with three industries. "Suppose we take 'Agriculture' and add one piece of 'Manufacturing' and one of 'Services' the two pieces being just large enough to make agriculture self-sufficient. Then this is a gross output sub-system." One might characterize this sub-system as a self-contained agricultural industry vertically integrated only on the factor side. That is, the "farm gate" concept holds on the product or output side according to Gossling. Gossling argues that to enlarge the sub-system to include food and fiber processing is objectionable because (1) "output" of food processing industries has substantially changed in the last four decades giving index number problems in output measurement and (2) the input structure of agriculture and food and fiber processing industries would be too dissimilar to merge. Indeed food processing output has changed (precooked food and the like). But is the problem appreciably different from comparing a 1919 tractor with the current air-conditioned hydraulic models? Gossling's second objective about dissimilar input structure can be applied equally to "factor" industries. Since most of the empiric analysis is based on the agriculture sub-system as defined, the point is sufficiently important to warrant more than the brief rationale as noted in a single paragraph in the introduction.

Chapter I includes a review of some selected productivity literature in an attempt to convince the reader that the analysis of sub-system will indeed help bridge the gap between micro- and macro-economics. While the objective is laudable, the explanation of how this is to be accomplished is not convincing. In fact "the case for the sub-system" is better understood after reading Chapter II (sub-systems simply explained) unless the reader is familiar with Gossling's previous writings on this subject [1, 2].

Chapter II leads the reader through several simple numerical examples illustrating the measurement of sub-systems from conventional input-output tables. Eventually, the author arrives at a general algebraic definition of sub-systems that should be comprehensive to readers with only a minimum of mathematics training. Some discussion of shortcomings of the method as related to assumptions underlying traditional I–O models would be helpful to most readers.

Chapter III (Productivity Measures in the Context of the Sub-system) is largely concerned with the conceptualization and algebraic comparison of "partial" and "comprehensive" measures of productivity. In one of the largest tables on record (excluding I–O tables, of course) covering six pages, Gossling presents algebraic and verbal expressions for 17 indices (13 partial and four comprehensive or total). Detailed empirical comparisons are made for most of the indices presented in the large table for the period 1919–1960. For the student of index numbers this chapter contains a wealth of information; for some it may be more than one wants to know about productivity measures.

Chapters IV, V, and VI represent almost a separate study adopting a Robinsonian closed model to an empirical study of American agriculture *vis-à-vis* gross output sub-systems. The author performed a Herculean task of modifying I–O tables prepared by various researchers for different base years to allow meaningful comparisons of industry sectors over points in time (1919–1958). As one with meager experience in such data massage activities, Gossling's perseverance is commendable.

However, application of the Robinsonian model hinges in part on an assumption that the American agricultural economy is virtually closed with respect to international trade. I would argue that Gossling dismisses the implications of this questionable assumption a bit too summarily in less than one-half page. Possible extension of his work to a current year would require more careful evaluation of the implications of such an assumption.

In summary, the book represents a novel and scholarly attempt to enlarge our concepts of measurement of productivity for sub-system, however measured. Both theorist and empiricist will gain something by reading it. For possible extensions of this research, I would urge that serious consideration be given to broadening the definition of the agriculture sub-system to include the food and fiber complex.

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## References

[1] Gossling, W. F., "A New Economic Model of Structural Change in U. S. Agriculture and Supporting Industries," unpublished Ph.D. thesis, University of Illinois, 1964.

[2] ———, and F. Dovring, "Labor Productivity Measurement: The Use of Sub-systems in the Interindustry Approach and Some Approximating Alternatives," *J. Farm Econ.* 48:369–377, May 1966.

**Harberger, Arnold C., *Project Evaluation: Collected Papers*, Chicago, Markham Publishing Company, 1973, xii + 330 pp. ($15.00)**

In New York in 1959 I used to listen to a radio show on WBAI called "From the Midway." It was

a series of fascinating lectures on anthropology, history, social thought, and other topics coming from the University of Chicago. Here in *Project Evaluation* we have the written record of some of the economic advice dispensed to Canada, Spain, Brazil, India, Iran, Mexico, Columbia, Argentina, and elsewhere coming from the Midway (although he probably left from O'Hare).

These essays are characterized by a partial equilibrium approach. If general equilibrium analysis is applicable anywhere, it ought to be in the less developed countries where large projects are likely to have ramifications in many markets. Harberger scorns large-scale models, e.g., his treatment of linear programming (at pp. 58 ff.). His treatment of road projects differs considerably from the way Tinbergen or Bos and Koyck treat them. Harberger emphasizes questions of capital and discounting in which he excels. He is willing to alter market prices for shadow prices, yet he finds much information in the rate of return various industries are receiving.

Harberger answered several questions I had posed to myself without answering to my satisfaction. For example, at pp. 28 ff. he convinced me that the discount rate should vary over the business cycle not because of the Fisher effect but because of the changing scarcity and productivity of funds. He gives good examples of credible situations which might lead to multiple solutions for the internal rate of return. Realistic examples will be found here on the stage construction economies of roads and cases in which benefits depend on calendar time, not on the age of the project. There is a neat example of different attitudes toward risk in Chapter 11.

Harberger's world differs from that of domestic benefit-cost analysis. He confines himself to the more comfortable, measurable world of industrial projects which in this country is left to the corporate finance committees. Toilers in domestic public expenditure fields find themselves asked to evaluate time, human life, "environmental impact," "social well-being of people," and equity. His work is apolitical. The emphasis is entirely on efficiency. One looks in vain in the index for entries on income distribution, equity, or multiple objectives. This is a serious shortcoming in a book on developing countries. He apparently subscribes to Musgrave's normative theory of the public household in which the Office of Benefit-Cost Analysis in the Allocation Branch suboptimizes, assuming that the Distribution Branch will take care of equity through taxes and transfers.

Over this period domestic benefit-cost analysis by contrast has been preoccupied with the multiple objectives problem. Issues of income distribution over socioeconomic groups have always been with us. Local interests have long been preoccupied with regional economic development or geographic income distribution. Newly risen are the issues of ethnic income distribution and environmental impact. The best way to integrate these issues through side displays, commensurable weights, lexical orderings, adversary proceeding, or the creation of property rights is a major unsolved problem. Perhaps the first order of business for a poor country is efficiency.

Although he is clearly in the Chicago camp, he is not doctrinaire. He argues that the government should not display risk aversion because of its broad portfolio and thus supports Arrow and Marglin against those (friends of his) who would put risk premiums in discount rates.

Are these essays worth reprinting in a book? Yes. Benefit-cost analysis has a great deal to offer poor countries. Many of these essays appear in inaccessible places like the *Revista de Teoria e Pesquisa Economica* in Portuguese, yet they have application in many countries. Effective consulting is often education. Markham made this intelligence a collective good and (for other reasons) became insolvent. [You will have to order this book from Rand-McNally.]

For much of the material there exist alternative sources. In addition to Harberger's, two other important surveys of benefit-cost analysis appeared in 1965. P. D. Henderson's is stronger on constraints, risk, and reinvestment. Unfortunately, in its accessible form it is puzzlingly out of print. Prest and Turvey's well-known essay is superior on matters of second-best and applications, but the balance of *Project Evaluation* covers Harberger on the latter point. Part of his treatment of road evaluation is reminiscent of that by Alan Walters. There is some repetition among the essays, but this serves to underline points made succinctly in the surveys with useful, concrete applications.

Harberger's confession of a change of heart on the concept of the social rate of discount creates expectations of a dramatic conversion. From his pre-1968 preference for the marginal productivity of capital, he moved to a weighted sum including the marginal rate of time preference. Since the weight of the second term is the elasticity of private saving to changes in the interest rate, and this is likely to be low or zero, his change of heart is of small moment.

On p. 78 (and in Chapter 7) Harberger criticizes the view that the marginal product of labor is zero in India by showing that the implication is that all output has to be attributed to capital. This is true, strictly, only if the production function of the economy is homogeneous. Otherwise, weighting factors by their *marginal* productivities may be irrelevant to attributing product. I quarrel with his Table 12.1 at p. 315 which is simplistic and misleading. He tries to show that U. S. programmatic aid has had little impact on income per capita while advocating more emphasis on aid for individual projects. He assumes no depreciation, simply adds up total aid 1946–68 (there is a misprint in the column heading) and, least tenable, attributes a uniform 10 percent rate of return in each country. Dividing by population is more a comment on overpopulation than on the productivity of program and sector loans. There is no assurance that efficient proj-

ects will materially affect income per capita either.

I would recommend Harberger's book to just the type of technocrat he hopes to train. It is a good text for a World Bank Young Professional. It does not address the more subtle questions of benefit-cost analysis when output is intangible. The student will have to educate his sensibilities about income distribution elsewhere, and if impact on the natural environment is an issue, he will find no guidance here.

Despite these criticisms, I believe on balance that Harberger has been a light to the nations. Students from developing countries and those interested in development economics will profit from his broad experience and many concrete examples. Practitioners of benefit-cost analysis can find many points expounded here in an illuminating fashion. I am glad I read it.

Many of the important advances of the fifties were made at Chicago by those versed in finance and collected in Solomon's *The Management of Corporate Capital*. Later they were applied by those interested in public investment. Here we have another offering recording efforts of the sixties from the Midway, that fountainhead of ideas on efficiency.

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**Harriss, C. Lowell, ed., *Government Spending and Land Values*, Madison, University of Wisconsin Press, 1973, xix + 239 pp. ($10.00)**

This volume is one in a series of compendia of symposium papers sponsored by the Committee on Taxation, Resources and Economic Development. The current papers were delivered at a symposium held in Madison, Wisconsin, in 1971. Like most such collections, the current one suffers from unevenness in the quality of the papers.

The general theme of the conference, according to the editor in his introduction, was the capitalization of subsidy benefits into land values. Agricultural subsidies are an obvious example, although most of the book is more concerned with housing, water, and transportation rather than agricultural expenditures. Harriss makes the point that capitalized losses from tax levies are well known and understood, but that less attention has been paid to the capitalized gains from expenditures. He subtitles the volume *Public Money and Private Gain*. But, therein it seems to this reviewer, at least, lies a problem.

The unwary, even within the economics profession, are apt to read such a title and have visions of "special interests" with their hand in the public purse. But things are not that simple. Public expenditures can impose losses as well as gains. A good example is highway construction. If a new highway is built that duplicates in part an old highway, then property owners with access to the new highway will receive capital gains, hopefully there will be efficiency gains for society, but in addition property owners along the old highway will probably suffer losses. (The same principle works on the tax side. A real property tax increase will lower land values. Holders of untaxed capital items should gain.) Several selections in the volume recognize this problem; my point is that policy inferences drawn from the introduction or summaries of the papers may be subject to reservations.

Two papers, one by Boxley and Anderson on tobacco, and one by Ballinger on sugar, will probably be of interest to quite a few readers of this *Journal*. Neither paper presents any new analytical insights into agricultural subsidy capitalization. However, they are very readable reviews of the past operation of these two programs and the incidence of the subsidies therefrom.

The remaining papers are concerned with introductory material, housing, transportation, and water resource development. Three of these papers actually come to grips with the real world. Given review space limitations, I can really only say much about two of these. The third by Coughlin and Hammer on open space preservation has a less well-specified problem and consequently less conclusive results.

A paper by Stern and Ayres concerns "Transportation Outlays, Who Pays and Who Benefits?" Their conclusions are quite straightforward. In part they demonstrate, among other things, non-users of various transport modes are not penalized very much; urban non-users of automobiles are penalized; benefits, especially in central business districts, are capitalized into land; and some thinking about revising tax policy is in order. Frankly, I found the going very difficult to get to the conclusions. I think this is because the study appears to be a summary of a much bigger undertaking for HUD. I should think interested persons would benefit from an expanded statement of what the authors are really doing.

The jewel in the book is a paper by Richard Muth on housing subsidies. By utilizing some new data Muth is able to estimate a CES production function for housing. This procedure enables him to disentangle the substitution of capital for current inputs in the production of housing, which he says he has been unable to do until now. His conclusions demonstrate that the current form of housing subsidies leads to real estate inputs being 37 percent greater, current inputs 25 percent smaller, and the resource cost of public housing about 20 percent greater than if residents were paid a direct rental subsidy. Underpinning these results is a very clear piece of craftsmanship in empirical economic analysis.

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**Markham, Jesse W., *Conglomerate Enterprise and Public Policy*, Boston, Graduate School of Business Administration, Harvard University, 1973, xviii + 218 pp. ($9.00)**

This short and readable book offers a general literature review and discussion of management and public policy issues related to the conglomerate merger movement of the 1960's, along with a variety of empirical observations, some based on original data, relating to this experience. The three principal empirical questions addressed are: (1) Is conglomerateness associated with the centralization of managerial decisions affecting market behavior (pricing, advertising, reciprocity)? (2) Is conglomerateness related to the level or change of concentration, either in the aggregate or in individual industries? (3) What other company characteristics are statistically related to conglomerateness? In all instances, conglomerateness is considered in both static and dynamic perspectives—i.e., the extent of diversification at some point in time and the change in diversification, particularly as a result of merger, over time.

The basic data collection for the original portions of the study consists of more than 200 usable answers from a survey of 600 large corporations. These responses are supplemented by additional data from the *Compustat* tapes, other Harvard Business School data collections, and Professor Charles Berry's company-diversification indexes. Markham has also drawn on the results of more extensive field interviews with an unspecified small number of large diversified firms. The author has done well to make maximum use of all information available to him; however, the reader will note that the empirical basis for the analysis varies substantially from table to table and paragraph to paragraph. A list of most of the responding companies is published in the appendix, but some respondents prefer to remain anonymous; and in any event, one would have no way of knowing what portion of the respondents were included in any of the more selective tables.

Nevertheless, taken at face value, the data presented in the central chapters of the volume constitute an addition to our knowledge of the large diversified firm. Markham confirms the conventional wisdom that top management in a large conglomerate enterprise is principally concerned with decisions involving large capital outlays, not with marketing variables. He found that pricing and advertising decisions in most of these companies "are left almost entirely to division or operating unit managers" and that reciprocity "was probably less likely" to be practiced by large conglomerates than by other corporations (p. 91).

Turning to the concentration question, Markham's main observation is that "there is no evidence that the recent conglomerate merger wave contributed to increased (aggregate) concentration for the simple reason that no increase appears to have occurred" (p. 117). Since Census data tabulated on the same page reveal that the share of the 200 largest corporations in total value added by manufacturing increased by 5 percentage points during the period 1958–70, and since this and the following supporting table are the only data for aggregate concentration presented in the entire volume, this conclusion seems, at best, hasty. Other studies have suggested that half or more of the relative growth of large firms in the economy during this period should be attributed to merger activity. Failure to consider these issues—apparently justified by the unexplained remark that value added is "a more meaningful measure" of firm size—constitutes a serious omission.

Markham is more concerned with the connection between diversification mergers and levels or changes in market shares or concentration at the industry level. He finds weak negative correlations between initial market share and diversification growth of acquiring companies, and mixed results (some increases, some decreases) with respect to the changes in concentration in the industries in which acquisitions were made.

In the search for variables associated with conglomerateness, Markham employs a pragmatic "open search" regression approach, rather than attempting to test a specific model. Companies included in the data are broken down into consumer and producer goods categories, particularly in order to examine any special effects of R & D expenditures in the former and advertising-selling expenditures in the latter. No such effects, however, are found. Perhaps the most interesting result of the regression analysis is that profitability and price earnings ratios, where statistically significant, were *negatively* related to both diversification and merger activity. It is not clear, of course, whether this indicates that diversification and mergers were unprofitable, or simply that these strategies were adopted by less-profitable companies in the hope of improving relatively unsatisfactory economic positions. All of the regression analysis is plagued by the absence of theoretical underpinning and by variability in the number and sampling validity of observations included. (One regression involves data for only 10 firms, for example.)

It is not surprising that this highly selective group of empirical analyses does not yield any general conclusions. Although Markham begins the book with a broad survey of the literature and policy issues, the concluding chapter offers little to advance our thinking beyond the introduction. In a sense Markham is correct that his results "derive almost as much importance from what they did not establish" (p. 161). Certainly their ambiguity will be welcomed by those who hope that no reason will ever be found for serious public policy initiatives to curb giant firm growth, particularly by merger. On the other hand, persons of a contrary persuasion will have little

difficulty discounting Markham's results as highly particularistic, selective, and subject to serious (and clearly acknowledged) limitations in both the quality and coverage of the basic data.

Lee E. Preston
*State University of New York at Buffalo*

**Shaw, Edward S., *Financial Deepening in Economic Development*, New York, Oxford University Press, 1973, xii + 260 pp. ($7.50 cloth, $3.50 paper)**

This is an instructive book as much for its flaws as for its insights. Financial deepening is said to occur when stocks of financial assets grow relative to aggregate income or in proportion to tangible wealth. Where finance is shallow, demand for financial assets is repressed by low real rates of interest, and the supply of primary securities on these terms is repressed by credit rationing; the economy must then depend relatively heavily on its government fiscal budget and on its international capital accounts for savings to finance capital growth. Liberalization by contrast permits the financial process of mobilizing and allocating savings to displace in some degree the fiscal process, inflation, and foreign aid. The financial system is thus thought to matter in economic development.

There is a tendency throughout the book to claim a little too much for its insights, but this is resisted. The argument for liberalization in finance is that scarcity prices for savings increase rates of saving, improve savings allocation, induce some substitution of labor for capital equipment, and assist in income equalization. A strategy of financial liberalization, the author claims, has invariably renewed development. Nevertheless, the reader is also warned that what liberalization can do is "difficult even to measure and describe precisely, given the context of disarray in which it is applied." Perhaps all that can be said with confidence is that inflation as a method of generating savings may be counterproductive, particularly when it is associated with restraints on interest rates.

The author is confident that ample investment opportunities will emerge "when firms need to put less effort and expense into obtaining loan rations or import licenses, export permits, or foreign-exchange allowances from an overburdened civil service." He does discuss perhaps too cavalierly the widespread concern that "only the larger and older trading firms, their roots established in some earlier colonial period," can supply the loan opportunities at scarcity prices. The arguments he cites for high underlying rates of return in lagging economies are probably the weakest part of the book. He is certainly wrong to claim that if doubts on this score are justified, "the lagging economy is destined always to be a lagging economy." Low rates of return may merely define the problem for development.

Though concerned with policy, the book nevertheless exhibits considerable perplexity about politics. Why countries adopt strategies of financial repression is not clear to the author, he candidly admits. It may be inadvertence, mistrust of market forces, or perhaps a reflex to experience with colonialism in one form or another. The consequence is, in any case, that monetary authorities have come to be monetary boards dominated by ministers of finance and planning. Hence, for the author, it must be a principal purpose of liberalization to substitute markets for "bureaus." This line of thought seems excessively ideological. A more pragmatic approach to improving past policies would, however, require a greater effort than is found here to grasp rather than moralize about politics.

The author rests content with monetary theory as the necessary grounding for analysis of financial repression and liberalization. Expounding it seems to require an inordinately long explanation of what the world is *not* like, however. Regrettably, conventional theory "has not been refined for the subtle context of development." Output is not putty nor is foresight perfect. Nevertheless, failure to heed some of the implications of thinking so "have cost lagging economies dearly." Though one may sympathize with all the burden of intellectual effort that comes begging for relevance here, there is a rather parochial air about arguments of this kind. One could have hoped for a fresher, less encumbered treatment of what is, after all, an interesting and important thesis.

Hans O. Schmitt
*International Monetary Fund*

**Wildsmith, J. R., *Managerial Theories of the Firm*, New York, the Dunellen Company, 1974, iv + 140 pp. ($10.00)**

This small book brings together and compares the work of several writers in the area of managerial economics (mainly Baumol, Williamson, and Marris). It makes no effort to offer original extensions and enters debate over conflicts only to a modest extent. The primary focus is identifying areas of "managerial discretion" in the operating policies of large corporations. Behavior patterns associated with growth incentives, concern for take-over, and organization theory are included as alternatives to traditional profit maximization.

The strongest part of the book is that it brings together, in very compact and readable form, the leading models and theories of managerial behavior. Financial planning is the most developed area of managerial strategy.

The major weaknesses are those general to the field of work. Non-material objectives or incentives of managerial individuals or groups are written off—not because they are unimportant but because they

are unmanageable. The process of consumer product experimentation is hardly dealt with although it is important to managers and to society. Advertising is seen as a "sales lubricant" almost unrelated to the process of product experimentation.

Professionals in managerial economics will find little value here. On the other hand, students and many professionals in other specializations may find this an efficient and convenient introduction to an interesting and important subject.

DANIEL I. PADBERG
*Cornell University*

*Books for listing in this section should be sent to the Book Review Editor (see inside front cover for address.)*

# Books Received

**Barberis, Corrado,** *Sociologia Rurale,* 2nd ed., Bologna, Edizioni Agricole, 1973, xx + 236 pp. Price Unknown. Paper.

**Bird, Richard M.,** *Taxing Agricultural Land in Developing Countries,* Cambridge, Harvard University Press, 1974, xvi + 361 pp. $14.50.

**Bishay, Fahmi K.,** *Models for Spatial Agricultural Development Planning,* Rotterdam, Rotterdam University Press, 1974, xv + 172 pp. Dfl. 35.00.

**Breman, Jan,** *Patronage and Exploitation: Changing Agrarian Relations in South Gujarat, India,* Berkeley, University of California Press, 1974, xvi + 287 pp. $15.00.

**Brown, Gilbert T.,** *Korean Pricing Policies & Economic Development in the 1960s,* Baltimore, The Johns Hopkins University Press, 1973, xv + 317 pp. $12.50.

**Carlos, Manuel L.,** *Politics and Development in Rural Mexico: A Study of Socio-Economic Modernization,* New York, Praeger Publishers, Inc., 1974, xv + 128 pp. $13.50.

**Clark, Colin,** *The Value of Agricultural Land,* Oxford, Pergamon Press, 1973, viii + 117 pp. $8.25.

**Cleave, John H.,** *African Farmers: Labor Use in the Development of Smallholder Agriculture,* New York, Praeger Publishers, Inc., 1974, xvi + 253 pp. $17.50.

**Cochrane, James L., Samuel Gubins, and B. F. Kiker,** *Macroeconomics: Analysis and Policy,* Glenview, Scott, Foresman and Company, 1974, xiv + 398 pp. $11.50.

**Damachi, Ukandi Godwin,** *The Role of Trade Unions in the Development Process: With a Case Study of Ghana,* New York, Praeger Publishers, Inc., 1974, x + 175 pp. $15.00.

**Denman, D. R.,** *The King's Vista: A Land Reform which has Changed the Face of Persia,* Berkhamsted, Geographical Publications Limited, 1973, xv + 368 pp. £ 6·50.

**Hewes, Leslie,** *The Suitcase Farming Frontier: A Study in the Historical Geography of the Central Great Plains,* Lincoln, University of Nebraska Press, 1973, xv + 281 pp. $10.00.

**Holland, Stuart,** ed., *The State as Entrepreneur, New Dimensions for Public Enterprise: The IRI State Shareholding Formula,* New York, International Arts and Sciences Press, Inc., 1973, x + 326 pp. $10.00.

**Johnson, D. Gale,** *World Agriculture in Disarray,* London, Fontana/Collins, 1973, 304 pp. $4.95. Paper.

**Kintis, Andreas A.,** *The Demand for Labour in Greek Manufacturing,* Athens, Center of Planning and Economic Research, 1973, 179 pp. Price Unknown. Paper.

**Lee, Dong-Bai,** *Economic Survey of Fertilizer Situation in the Asian and Pacific Region,* Taiwan, Food and Fertilizer Technology Center, 1973, x + 198 pp. Price Unknown. Paper.

**Lewis, W. Cris, Jay C. Andersen, Herbert H. Fullerton, and Delworth Gardner,** *Regional Growth and Water Resource Investment,* Lexington, D. C. Heath and Company, 1973, xi + 172 pp. Price Unknown.

**Lindholm, Richard W.,** *Taxation of Timber Resources To Maximize Equity and Wood Fiber Production: An Oregon Case Study,* Eugene, Bureau of Business and Economic Research, University of Oregon, 1973, v + 91 pp. $5.00. Paper.

**Lynn, Robert A.,** *Basic Economic Principles,* 3rd ed., New York, McGraw-Hill Book Company, Inc., 1974, xii + 398 pp. Price Unknown.

**Moav, Rom,** ed., *Agricultural Genetics: Selected Topics,* New York, John Wiley & Sons, 1974, xxxix + 352 pp. Price Unknown. Paper.

**Nickson, Jack W., Jr.,** *Economics and Social Choice,* 2nd ed., New York, McGraw-Hill Book Company, 1974, xiv + 328 pp. $5.95.

**Robinson, Roland I., and Dwayne Wrightsman,** *Financial Markets: The Accumulation and Allocation of Wealth,* New York, McGraw-Hill Book Company, Inc., 1974, viii + 439 pp. $12.50.

**Schaffer, Bernard,** ed., *Administrative Training and Development: A Comparative Study of East Africa, Zambia, Pakistan, and India,* New York, Praeger Publishers, Inc., 1974, vii + 445 pp. $22.50.

**Seibel, Hans Dieter, and Andreas Massing,** *Traditional Organizations and Economic Development: Studies of Indigenous Cooperatives in Liberia,* New York, Praeger Publishers, Inc., 1974, xxii + 264 pp. $18.50.

**Stein, Walter J.,** *California and the Dust Bowl Migration,* Westport, Greenwood Publishing Company, Inc., 1973, xiv + 302 pp. $12.00 Cloth, $3.45 Paper.

**Suter, Robert C.,** *The Appraisal of Farm Real Estate,* Danville, The Interstate Printers & Publishers, Inc., 1974, xi + 613 pp. $14.50.

**Tarrant, John R.,** *Agricultural Geography,* New York, John Wiley & Sons, Inc., 1974, 279 pp. $12.50.

**Troelstrup, Arch W.,** *The Consumer in American Society: Personal and Family Finance,* 5th ed., New York, McGraw-Hill Book Company, Inc., 1974, xvii + 678 pp. $11.50.

**Whiting, Larry R.,** ed., *Rural Industrialization: Problems and Potentials,* Ames, The Iowa State University Press, 1974, x + 153 pp. $4.95. Paper.

**Wilcox, Walter W., Willard W. Cochrane, and Robert W. Herdt,** *Economics of American Agriculture,* 3rd ed., Englewood Cliffs, Prentice-Hall, Inc., 1974, viii + 504 pp. $14.95.

# Announcements

## AAEA-ASSA 1974 WINTER MEETING

The American Agricultural Economics Association will meet jointly with the Allied Social Sciences Associations in San Francisco, December 28–30. A complete program will be published in the November *AJAE*.

Sessions are scheduled in the following areas: Structural Changes in the Food Industry: Implications for Future Public Policy; Recent Resource Problems of Less Developed Countries; and Evaluation of Econometric Models for Forecasting within the Agricultural Sector and the Total Economy.

## NEW AJAE BOOK REVIEW EDITOR

Starting with the February 1975 issue, the new Book Review Editor for the *American Journal of Agricultural Economics* will be Francis E. Walker. After August 1 new submissions of book reviews or books for listing in the "Books Received" section should be sent to Professor Walker, Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus, Ohio 43210.

## INTERNATIONAL ASSOCIATION OF SURVEY STATISTICIANS (I.A.S.S.)

This Association was established as a new section of the International Statistical Institute (I.S.I.) in 1971. According to the Statutes, "The objectives of the Association shall be to promote the study and development of the theory and practice of statistical censuses and surveys and associated subjects and to foster interest in these subjects among statisticians, organizations, institutions, governments and the general public in different countries of the world."

Those interested in the promotion of these objectives are invited to become members of the association. Annual membership dues are US$5.00 (or the equivalent in other currencies) for citizens of the less developed countries in Asia, Africa, and Latin America. Dues for all other members are fixed at US$10.00 (or the equivalent in other currencies). Send membership fees, name, and address to:

Mr. Paul Damiani, Secretary
International Association of Survey Statisticians
c/o I.N.S.E.E.
29, Quai Branly
Paris 75700—France

The objectives of the Association are to be accomplished through: (1) international meetings held biennially, at which papers will present new developments in survey methods and will serve more generally as a means of communication among survey statisticians (the first meeting was in 1973 in Vienna, and the next will be in 1975 in Warsaw, arranged to coincide with the meetings of the International Statistical Institute); (2) publication of proceedings of meetings, newsletters, and material reporting on activities of the Association, and other events of interest to survey statisticians; (3) other activities may include such functions as training sessions, advice on major international statistical programs, assistance in recruiting for governmental and other major statistical organizations, and encouragement of regional chapters of the I.A.S.S.

## SOUTHERN AGRICULTURAL ECONOMICS ASSOCIATION 1974 ANNUAL MEETING

The SAEA 1974 annual meeting was held February 3–6 in Memphis, Tennessee. Major themes of the invited papers were Agricultural Prices in the 1970's, Rural Development, and Research Planning, Conduct, and Management.

## SOVIET RURAL BIBLIOGRAPHY AVAILABLE

The Ford Foundation offers *A Selected Bibliography on Rural Development in Socialist Countries.* This unique bibliography consists of writings from Soviet Bloc countries rather than Western scholars, with most items from 1969–1973 publications. Among the topics included are the planning and management of rural construction, rural credit, rural medical services, rural libraries, extension services, and agricultural development. Copies are available on request to the Office of Reports, The Ford Foundation, 320 East 43rd Street, New York, New York 10017.

## SOUTHERN REGIONAL SCIENCE ASSOCIATION

The Southern Regional Science Association will hold its 1975 meetings in Atlanta on April 3–4. Scholars interested in presenting papers on any subject involving analysis of the spatial dimensions of human activity are invited to submit one-page abstracts by October 1, 1974, to the program chairman, Professor William H. Miernyk, Regional Research Institute, 4 Main Library, West Virginia University, Morgantown, West Virginia 26506.

# News Notes

## UNIVERSITY OF ARKANSAS

APPOINTMENT: **Owen E. Smith,** M.S. University of Arkansas, as instructor in agricultural economics and rural sociology.

## THE UNIVERSITY OF ALBERTA

APPOINTMENT: **Saiyed M. H. Rizvi,** Ph.D., to the Agricultural Economics Research Council of Canada, Ottawa.

LEAVE: **Murray H. Hawkins,** associate professor, on sabbatical July 1974 to July 1975 at the University of New England, Armidale, New South Wales, Australia.

RETURN: **H. C. Love,** professor, from appointment as visiting professor at the University of Science and Technology, Kumasi, Ghana.

## THE UNIVERSITY OF ARIZONA

REASSIGNMENT: **Thomas Stubblefield** has resumed his position as professor after serving as Assistant to the Director of the Experiment Station.

## THE UNIVERSITY OF CHICAGO

HONOR: **Theodore W. Schultz** received the Distinguished Service Award from the American Agricultural Editors Association for 1973 and was named a Member of the National Academy of Sciences, 1974.

## CLEMSON UNIVERSITY

RESIGNATION: **William J. Lanham,** Head, Department of Agricultural Economics and Rural Sociology, to the Coastal Plains Regional Commission, Washington, D.C.

## COLORADO STATE UNIVERSITY

APPOINTMENTS: **Lawrence E. Mach,** formerly with the University of Arizona, as assistant professor; **Edward W. Sparling,** Ph.D. candidate, University of Wisconsin, as instructor in economics.

## UNIVERSITY OF FLORIDA

APPOINTMENT: **Bennet Abbitt,** M.S. University of Georgia, as rural development economist.

RESIGNATION: **Wen Shyong Chern,** formerly research economist with the Florida Department of Citrus, to become research associate for environmental programs at Oak Ridge National Laboratories, Oak Ridge, Tennessee.

## UNIVERSITY OF GUELPH

APPOINTMENT: **R. W. Archibald,** Ph.D. candidate, University of Western Ontario, to a teaching and research position in agricultural business.

RESIGNATION: **R. G. Marshall,** professor, to the Marketing and Trade Division, Economics Branch, Agriculture Canada.

## UNIVERSITY OF HAWAII

LEAVES: **Heinz Spielmann,** sabbatical to conduct research in the National Economic Accounts Division of ERS, one year effective September 1, 1974; **Hiroshi Yamauchi,** sabbatical, to be visiting professor and to conduct advance study in natural resource economics at the University of Wisconsin, one year effective September 1, 1974.

## UNIVERSITY OF IDAHO

APPOINTMENTS: **John E. Carlson,** U.I. sociology faculty, to split research appointment in agricultural economics; **Douglas L. Grant,** U.I. College of Law faculty, to split research appointment in agricultural economics; **James R. Nelson,** Ph.D. Oklahoma State, as Extension Community Resource Development Specialist; **Joseph C. Roetheli,** M.S. Florida, as research associate in agricultural economics; **H. Lee Schatz,** M.S. Idaho, as research associate in agricultural economics.

## UNIVERSITY OF ILLINOIS

HONOR: **C. Allen Bock** has been awarded a Certificate of Recognition by the federal Internal Revenue Service for his work in the development of the Illinois Farm Income Tax School Workbook.

REASSIGNMENT: **Richard L. Feltner** has been named Assistant Secretary of Agriculture for Marketing and Consumer Services, Washington, D.C.

## IOWA STATE UNIVERSITY

RESIGNATIONS: **Bruce R. Beattie,** associate professor, to Texas A & M University; **Leo V. Mayer,** associate professor and associate director of the Center for Agricultural and Rural Development, to the Library of Congress, Washington, D.C.

RETIREMENT: **William G. Murray,** professor, effective June 1, 1974 after serving 45 years with the university.

*UNIVERSITY OF KENTUCKY*

Appointment: **Alan T. Randall,** formerly with New Mexico State University, as assistant professor.

*UNIVERSITY OF MAINE, ORONO*

Leave: **Kenneth E. Wing,** Department Chairman, from September 1974 to June 1975 to accept a fellowship in Academic Administration sponsored by the American Council on Education.

*THE UNIVERSITY OF MANITOBA*

Appointment: **Om P. Tangri,** associate professor, appointed member of the Manitoba Economic Development Advisory Board.

*UNIVERSITY OF MARYLAND*

Appointment: **Martin A. Abrahamsen** for two years as visiting professor; Dr. Abrahamsen retired in 1973 after 24 years with the USDA's Farmer Cooperative Service and its predecessor agency.

*MICHIGAN STATE UNIVERSITY*

Leaves: **Donald Ricks,** sabbatical July 1974 to January 1975, to study the European fruit industry; **A. Allan Schmid,** sabbatical June to December 1974, to study in France and write in East Lansing.

Resignation: **Dale Hathaway,** professor, effective August 1, 1974, to continue work with the Ford Foundation.

Retirements: **Lauren H. Brown,** professor of farm management, effective June 30; **C. Raymond Hoglund,** professor of farm management, effective in October.

*UNIVERSITY OF MISSOURI*

Appointments: **Stephen F. Matthews,** Ph.D. Missouri, as instructor; **Joseph C. Meisner,** Ph.D. Missouri, as State Agricultural Economics Extension Specialist-Consumer Information.

Leave: **Randall Torgerson,** to Agricultural Marketing Service, USDA, for two years.

*THE UNIVERSITY OF NEBRASKA*

Appointment: **Ronald Hanson,** Ph.D. Illinois, as assistant professor in farm management and agricultural finance.

*NORTH DAKOTA STATE UNIVERSITY*

Resignations: **Ronald G. Fraase,** assistant professor, to accept position as marketing specialist with the North Dakota State Wheat Commission, Bismarck, effective April 1, 1974; **Donald M. Senechal,** instructor, to accept position with Arthur D. Little, Inc., Cambridge, Massachusetts, effective November 1, 1973.

*OHIO STATE UNIVERSITY*

Appointment: **Lynn Forster,** Ph.D. Michigan State, as assistant professor in farm management.

Retirement: **Richard H. Baker,** professor, after 37 years of service.

*OKLAHOMA STATE UNIVERSITY*

Appointments: **Marc Johnson** as assistant professor in the area of economics of transportation; **Gary Mennem** as assistant professor and extension economist in the areas of economics of transportation and grain marketing.

*OREGON STATE UNIVERSITY*

Assignments: **Ludwig Eisgruber,** Professor and Head of Department of Agricultural Economics, has been named a member of the Advisory Committee to the State Department of Economic Development; **A. Gene Nelson,** assistant professor, has been appointed to the Oregon Governor's Task Force on the Boardman Navy Land Development.

*PURDUE UNIVERSITY*

Appointments: **Paul L. Farris,** professor, became Head of Agricultural Economics, effective March 15, 1974; **John E. Kadlec,** professor, became assistant head of the department in charge of teaching, for a three-year term; **Earl W. Kehrberg,** professor, became assistant head of department in charge of research, for a three-year term; **Glenn L. Nelson,** assistant professor in community development; **Robert L. Thompson,** assistant professor in international trade.

Leave: **Arlo J. Minden,** to AID, Department of State, Washington, D.C., for one year.

Resignations: **David L. Debertin,** to University of Kentucky as assistant professor in natural resources-production; **Frederick W. Obermiller,** to Oregon State as assistant professor in community resource development.

Return: **Robert W. Taylor,** professor, after two years with the Purdue-Brazil Project, Vicosa, Brazil.

Transfer: **John B. Penson, Jr.,** from Inputs and Finance Program, NEAD, ERS, USDA, Washington, D.C., to same program as assistant professor at Purdue.

*UNIVERSITY OF RHODE ISLAND*

Assignment: **Virgil J. Norton,** professor, five months with the Instituto de Technologia de Alimentos, Campinas, Sao Paulo, Brazil, under sponsorship of the U. S. Consortium for the Development of Technology (CODOT) and the Council for Science and Technology of the State of Sao Paulo, Brazil.

*SOUTHERN ILLINOIS UNIVERSITY*

Retirement: **W. E. Keepper,** Dean of the School of Agriculture for 24 years, retired effective June 30, 1974.

Return: **Gordon Langford,** from a three-year as-

signment with the University UNDP/FAO Contract at Santa Maria, Brazil.

*VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY*

APPOINTMENT: **Joseph Havlicek, Jr.,** formerly with Purdue University, as professor.

RESIGNATION: **David Paul Miller,** to become Area Farm Management Agent, Ohio Extension Service.

*WASHINGTON STATE UNIVERSITY*

APPOINTMENT: **William H. Pietsch,** formerly with USDA–ERS, as associate professor and extension economist.

LEAVE: **Paul W. Barkley,** to Western Regional Rural Development Center, Corvallis, Oregon, for one year effective August 1 in conjunction with sabbatical leave.

*UNIVERSITY OF WISCONSIN*

APPOINTMENT: **Robert Rieck,** appointed Dean of the Division of Economic and Environmental Development, University of Wisconsin-Extension.

HONOR: **Richard Weigle,** farm business management specialist and Chairman of the Farm Business Management Program, awarded the USDA Superior Service Award for 1974.

RETIREMENT: **Kenneth Parsons,** after 37 years with the university, and appointed Emeritus Professor of Agricultural Economics.

*OTHER APPOINTMENTS:*

**Kenneth A. Becker,** M.S. Missouri, research economist, Oscar Mayer Co., Madison, Wisconsin.

**Derli Chaves Machado da Silva,** Ph.D. Louisiana State, to Institute for Space Research, Sao Jose dos Campos, Sao Paulo, Brazil.

**Jose P. Ramalho deCastro,** Ph.D. Purdue, to ACARES, Brazil.

**W. Graeme Donovan,** Ph.D. Cornell, economist, International Bank of Reconstruction and Development.

**William A. Hand,** M.S. Virginia Polytechnic Institute, to Agricultural Marketing Service, USDA.

**Michael J. Hay,** Ph.D. Minnesota, to the Environmental Protection Agency, Washington, D.C.

**Ralph G. Lattimore,** Ph.D. Purdue, economist, Ministry of Agriculture, Wellington, New Zealand.

**Gary D. Lee,** M.S. Missouri, marketing specialist, Prairie Farms Dairy, Carlinville, Illinois.

**Thomas W. Little,** Ph.D. Virginia Polytechnic Institute, to Commodity Economics Division, ERS–USDA.

**Lynn J. Maish,** Ph.D. candidate Minnesota, Office of Planning and Evaluation, USDA, Washington, D.C.

**Wendell M. McMillan** has concluded his World Bank assignment with the Caribbean Development Bank in Barbados, West Indies, and is transferring to Khartoum, Sudan, as the agricultural adviser on the World Bank Development Planning Team.

**Kenneth M. Menz,** Ph.D. Minnesota, returned to Australia.

**George Morse,** Ph.D. Minnesota, position in community development and public policy at South Dakota State University.

**Ronald F. Mueller,** M.S. Missouri, associate manager, Federal Land Bank, Boonville, Missouri.

**Julio A. Penna,** Ph.D. Purdue, visiting professor, Universidade Federal de Vicosa, Minas Gerais, Brazil.

**Barry M. Popkin,** Ph.D. Cornell, with the Rockefeller Foundation as assistant professor at the University of the Philippines.

**Charles Powe,** Ph.D. Florida, Farmer's Cooperative Service, USDA, Washington, D.C.

**Nimal Sanderatne,** Ph.D. Wisconsin, Central Bank of Sri Lanka.

**Bruce A. Scherr,** Ph.D. Purdue, economist, Data Resources, Inc., Lexington, Massachusetts.

**Gerald D. Schwab,** Ph.D. Purdue, assistant professor, Michigan State.

**John L. Smith,** M.S. Purdue, agricultural economist, Dairymen, Inc., Louisville, Kentucky.

**Rubens Valentini,** Ph.D. Purdue, assistant professor, Universidade de Sao Paulo, Brazil.

**James C. Vogelsang,** M.S. Virginia Polytechnic Institute, to the Agricultural Division, Bureau of the Census, Department of Commerce.

**Handy Williamson, Jr.,** Ph.D. Missouri, associate director of Rural Development Research and assistant professor of agricultural economics, School of Applied Sciences, Tuskegee Institute, Alabama.

**Cristian P. Zegers,** Ph.D. candidate Minnesota, Instituto de Economia Agraria, Universidad Austral de Chile, Valdivia, Chile.

## OBITUARIES

**Gerald W. Dean,** Professor of Agricultural Economics at the University of California, Davis, died of cancer April 26, 1974.

Born in 1930 in Iowa, he was graduated from Iowa State University with a B.A. degree in 1952, an M.S. degree in 1955, and the Ph.D. degree in 1957. He joined the faculty at Davis late in 1957.

Gerry Dean compressed into a short 16 years at Davis a record of quality, achievements, and professional contribution that is truly outstanding. As a teacher he was clearly the best in a department that prides itself on its concern for students. His lectures reflected Dr. Dean's orderly and scholarly thinking, his unique perspective, and his concern that students truly understand.

The same qualities that helped to make him an outstanding teacher were evident in his research. His selection of problems reflected his concern for matters of importance and significance. His orderly approach and insight brought seemingly

diverse and disparate facts into perspective. He collaborated and shared ideas unselfishly with students and colleagues alike.

His professional interests were generally in the area of agricultural production, economic theory, and economic development. The professional awards he received are impressive. He was honored with eight research awards and four honorable mention awards from the American Agricultural Economics Association and the Western Agricultural Economics Association.

In 1962 and again in 1967, Dr. Dean received Fullbright fellowships to study and assist in graduate training at the University of Naples in Italy. He spent 1972–73 in Chile working with faculty and students at the Catholic University and the University of Chile under the auspices of the Ford Foundation. He had also aided the Ford Foundation in Brazil and Argentina.

Indeed, to say that Dr. Dean was a highly respected professional economist understates what he meant to his colleagues and students, because he was in a class by himself—a true scholar, teacher, and warm friend, with a keen sense of perspective as to what is important in work and life.

He also was active in professional and civic matters, serving as associate editor of the *American Journal of Agricultural Economics* from 1969 through 1971 and as vice president of the Western Agricultural Economics Association in 1971. He was a talented musician, arranging musical scores and playing in several local bands and orchestras, and was a former president of the Davis Art Center.

Immediate survivors include his wife, Meredith, and three children, Martin S., a student at the University of California, Berkeley, Anthony C., and Andrea, both attending Davis High School.

**Leonard Knight Elmhirst,** founder of the International Association of Agricultural Economics, died April 16, 1974, in Beverly Hills, California. His passing ends a long and distinguished career in agricultural economics.

Dr. Elmhirst was born in Laxton Vicarage, Yorkshire, England, in 1893. He was educated at Cambridge and Cornell Universities. He received honorary doctorate degrees from Freiburg University, Germany, and from the University of Oxford, England. In 1925 he married Dorothy Whitney Straight. In 1960, in recognition of his outstanding achievements, he was elected a Fellow of the American Agricultural Economics Association.

He guided the International Association for more than 30 years as its president, building an organization which now has some two thousand members in 83 countries. He was also mainly responsible for the establishment, by the Dartington Hall Trust, of the Institute of Agricultural Economics at the University of Oxford. The Institute publishes the *International Journal of Agrarian Affairs* and edits the *Proceedings* of the triennial conferences of the International Association of Agricultural Economists. For over 20 years he was Chairman of the Executive of the Agricultural Economics Society of Great Britain, and President in 1949–50. He also served on the Executive of the Royal Society of Forestry for England and Wales for several periods and for a term as its President. He served on the National Parks Committee for Great Britain in 1948–52.

Dr. Elmhirst was always interested in education in its broadest sense and believed that balance between the needs of the body and those of the mind and spirit benefited individuals as well as human relations.

**Helen Cherington Farnsworth,** professor emeritus and former associate director of the Food Research Institute at Stanford University, died February 23, 1974, at Stanford at the age of 71. She combined a long and distinguished professional career with marriage to Professor Paul Farnsworth of Stanford's psychology department and the rearing of a son and daughter.

A native of Columbus, Ohio, and the recipient of B.A. and M.A. degrees from the Ohio State University, Professor Farnsworth came to Stanford in 1926 and received her doctorate in economics from the University in 1930. She was a staff member of the Food Research Institute from 1929 until her retirement in 1968 and served on the Advisory Board and other major academic committees at Stanford.

She was recognized as an authority in the field of commodity economics. Her publications include many Food Research Institute monographs and articles in the *Journal of Farm Economics*, the *American Economic Review*, the *Quarterly Journal of Economics*, the *Journal of Political Economy*, and the *Economic Journal* (London). Her last work was the updating of a monograph she had published with Karen Friedmann (*French and E.E.C. Grain Policies and their Price Effects 1920–1970*) to include food consumption, grain feeding, and international trade in grain in the expanding European Community.

Dr. Farnsworth had been a member of many state and national committees on nutrition and a consultant to the National Institutes of Health. She was listed in *Who's Who in the World* and *Who's Who in America*.

**Kelsey Beeler Gardner** died on January 20, 1974, of a heart attack while on vacation in Florida.

He was born in Leonardville, Kansas, on July 6, 1892. His undergraduate work was at Washburn College in Topeka. He worked from 1914–16 on the photo service staff of the University of Illinois and was an instructor in the U. S. Army Aerial Photographic School at Rochester, New York. In 1922 he received his M.B.A. from the Harvard

Graduate School of Business Administration and joined the Cost of Marketing Division in USDA's Bureau of Agricultural Economics.

His early interest in the business methods of cooperatives grew continually. In 1926 Professor Gardner joined the BAE's Division of Cooperative Marketing. When the Federal Farm Board was created in 1929, he was made economist in charge of the fruit and vegetable section. From 1933 to 1939 he directed the fruit and vegetable work of the Cooperative Research and Service Division of the Farm Credit Administration. In 1939 a Business Administration Section was set up under his direction to focus attention on business organization and organizational problems common to all cooperatives. During World War II he was a member of the division's planning committee which helped maximize the contributions of cooperatives to the war effort.

After the war Professor Gardner represented the government at over 75 meetings throughout the U. S. on problems confronting agricultural cooperatives. In 1947 he began working with the Food and Agriculture Organization on cooperative programs to improve the economies of developing nations. He participated in six international conferences and directed the Farmer Cooperative Services program of assistance to foreign visitors studying U. S. cooperatives.

When the Farmer Cooperative Service was established as a separate agency of the USDA in 1953, Professor Gardner became director of its Management Services Division, a position he held until his retirement in 1962.

He received many honors during his long government career. In 1948 the American Institute of Cooperation presented him with its distinguished service award. In 1955 he received a merit citation from the National Civil Service League. In 1958 he received the Washburn University Alumni Association award for "distinguished service in community, state, and nation."

He is survived by his wife Katherine. In April they would have celebrated their golden wedding anniversary. He was very proud of his two children, John Kelsey Gardner, a research geophysicist at U.C.L.A., and Katherine Ann Gardner, a reference specialist at the Library of Congress.

**Edwin G. Nourse**, 90, first Chairman of the Council of Economic Advisers and former Vice President of the Brookings Institution, died on April 7 in Maryland.

Born in Lockport, New York, on May 20, 1883, he grew up in Chicago. His undergraduate training was obtained at Lewis Institute, now the Illinois Institute of Technology, and at Cornell University. He was granted the Ph.D. degree, *magna cum laude*, in economics and sociology by the University of Chicago in 1915; his dissertation was published as a Hart, Shaffner and Marx prize essay under the title *The Chicago Produce Market*. This book has been acclaimed as the first empirical study of the marketing process.

Dr. Nourse began his professional career as an instructor in finance at the Wharton School of Finance and Commerce in 1909, and he later headed departments of economics and sociology at the University of South Dakota, the University of Arkansas, and at Iowa State College before he joined the Institute of Economics in 1923 to direct its agricultural studies. When the Institute of Economics became part of the newly formed Brookings Institution in 1927, he became its director and from 1942 to 1946 served as Vice President. In 1946 President Truman named him as the first Chairman of the Council of Economic Advisers. Following his retirement from that position in 1949, he became Vice Chairman of the Joint Council on Economic Education and a consultant on economic problems.

Dr. Nourse was a recognized leader in the economics profession. He served as President of the American Farm Economic Association in 1924 and of the American Economic Association in 1942. From 1925 to 1946 he was actively associated with the Social Science Research Council and was its Chairman from 1942 to 1945. He was a pioneer in economic thinking and methodology, particularly in marketing theory. He was a champion of the institutional approach, for he believed that economic problems need to be considered in their historical and environmental setting. He took a leading role in the advancement of cooperative organizations and was one of the founders of the American Institute of Cooperation in 1925. He was one of the first to perceive the importance of pricing policy and economic planning.

His great literary skill and analytical capacity were reflected in a dozen books and hundreds of reports, pamphlets, articles, and reviews related to agricultural economics and general economics and social science subjects. His outstanding books were *Agricultural Economics* (1916); *The Legal Status of Agricultural Cooperation* (1927); *America's Capacity to Produce* (1934); *Price Making in a Democracy* (1944); and *Economics in the Public Service* (1953).

Dr. Nourse's chief claim to fame came from his direction of the Council of Economic Advisers during its formative years. From 1946 to 1949 he established the Council as a going concern to help guide the nation's economic policies, and he imparted to it his high standards of professional integrity and competence.

Many honors came to Dr. Nourse during his long professional career. Honorary degrees were conferred on him by the University of Chicago, the Illinois Institute of Technology, and Iowa State University, and he was the recipient of the Rosenberger medal of the University of Chicago in

1959. The American Farm Economic Association named him a founding Fellow in 1957, and the American Institute of Cooperation recently presented him with a special award for his unique contributions to cooperative theory and development.

For the past five years Dr. Nourse had worked on a book to bring together what he learned during his lifetime as a social scientist. The manuscript reflects his deep sympathy for his fellow man and woman regardless of race, color, or creed, and it offers hope for the future of mankind.

**Oscar Clemen Stine,** a pricing and marketing specialist with the U. S. Department of Agriculture for 37 years, died March 28 at the age of 89 in Shepherdstown, West Virginia.

Born in Sandyville, West Virginia, Dr. Stine graduated from Ohio University and received his Ph.D. at the University of Wisconsin in 1921. First associated with the Department of Agriculture in 1914 as a collaborator while at the University of Wisconsin, he went to Washington in 1916 as an economist in the Office of Farm Management. He developed and was first head of the Statistical and Historical Research Division of the Bureau of Agricultural Economics (1921).

The price and income research and standardized statistical procedures carried on under his direction created a firm research basis for determination of parity prices and estimating farm income. He was also responsible for much of the pioneering work done by the Bureau in the fields of commodity price and demand analysis. Interested in the relation of foreign economic conditions to American agriculture, he established the first departmental unit for economic analysis of foreign competition and demand. On various occasions he served as the department's consultant or delegate abroad.

Dr. Stine emphasized the need for careful study of past and present events to judge the future accurately. His interest in preserving and disseminating such study is reflected in his positions as editor of the *Journal of Farm Economics* in 1922–24, charter member of the Agricultural History Society and President of that society in 1924–25, first editor of *Agricultural History* during 1927–31, President of the American Farm Economic Association in 1931, secretary of the Social Science Research Council, 1939–40, a Fellow and Vice President of the American Statistical Association in 1939, founding member of the Central Statistical Board in 1933, and a Fellow of the American Farm Economic Association in 1959. He also taught at the University of Florida, Hampden-Sydney College, and Southern Illinois University.

Upon retirement from the Department of Agriculture in 1951, Dr. Stine and his family moved to a 120-acre farm in the Shenandoah Valley near Shepherdstown. While operating the farm, he continued a very active professional life. In 1959 he served as Associate Research Director of the Twentieth Century Fund study of government farm programs and briefly was Senior Specialist on Agriculture in the Legislative Reference Service of the Library of Congress. He was a member of the Jefferson County Historical Society, past president of the Jefferson County Planning Commission, and was listed in *Who's Who in America* and *American Scholars.*

His wife, Ruth Speerstra Stine, preceded him in death. He is survived by four children, Mrs. Stefan (Ruth) Fajans, Ann Arbor, Michigan; Miss Jane Stine, Baltimore, Maryland; Dr. Oscar C. Stine and John S. Stine, both of Lutherville, Maryland; eleven grandchildren, one sister, and one brother.

**Douglas C. Strong** died on March 11 after a short illness. He is survived by his wife, Dorothy, a son, Vaughn, and a daughter, Connie (Mrs. William Puzey).

Dr. Strong joined the Harza Engineering Company in Illinois on January 1, 1962. He advanced from Department Head to Division Head and then to Associate by 1968. In April 1971 he was named Chief Agricultural Economist and became the company's Chief Resources Economist in July 1973. He travelled abroad extensively for Harza in connection with many river resource development projects and had returned from a five-week assignment in Indonesia only five days before his death.

**Frederick Vail Waugh** died on February 16, 1974, in Arlington, Virginia after suffering a heart attack. He is survived by his wife, Irma, two daughters, a son, and 10 grandchildren.

Dr. Waugh was born in Burlington, Vermont, in 1898. He received his B.S. degree from Massachusetts College in 1922, his M.A. from Rutgers University in 1925, and his Ph.D. from Columbia University in 1929. He joined the Bureau of Agricultural Economics in 1928. In 1932–33 he studied in Europe as a Fellow of the Social Science Research Council, returning to work in the Division of Statistics and Historical Research, BAE, 1933–35. From 1935 to 1941 he was in charge of the Division of Marketing and Transportation Research. In 1938 he proposed a graduated price program to raise the consumption of surplus foods. The resulting Food Stamp Program began in 1939, was suspended during World War II, then resumed in 1961 as the major program assuring food to millions of low-income Americans.

He served as Assistant Administrator, Agricultural Marketing Administration, 1941–43; as Chief of the Program Appraisal Branch, Food Distribution Administration, 1943–45; Agricultural

Advisor, Office of War Mobilization and Reconversion, 1945–46; and Economist, Council of Economic Advisers, 1946–51. In 1951 he returned to BAE as Assistant Chief, later becoming Director of the Agricultural Economics Division, Agricultural Marketing Service, when BAE was abolished in 1953. Dr. Waugh was Director of the Division of Economic and Statistical Research of the Economic Research Service, 1961–65 and in 1961 received the USDA's highest honor, the Distinguished Service Award. He retired from the ERS in 1965.

Dr. Waugh was president of the American Agricultural Economics Association in 1946 and in 1957 was named one of the Association's first Fellows. Three different times—1952, 1957, and 1965—he won the award for the best article in this *Journal*. He edited the book *Readings on Agricultural Marketing*, published by the American Agricultural Economics Association in 1953.

He was best known professionally for his keen ability to apply economic theory to problem solving, and for his rare capacity to develop theoretical concepts and analytical techniques. His accomplishments in the use and development of economic analysis are numerous and varied, including conceptualization of the Food Stamp Program, the use of the concept of consumer surplus in studying the consequences of price variability, the application of linear programming methods to resource allocation problems in agriculture, pioneering efforts to quantify consumer indifference curves, and numerous mathematical proofs of economic and statistical theorems.

He was best known to his colleagues, however, for his wise and friendly counsel. The young and the old, the well-known and the little-known, all came to talk with Fred Waugh, and all were graciously received and welcomed. His advice and counsel inspired many a young man and set many a more experienced man straight. This was his great and lasting accomplishment as a colleague and friend.

# FINANCIAL MANAGEMENT

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The objective of the association is to further the development of systematic knowledge of agricultural economics for the purpose of improving agriculture and agriculture's contribution to the general economy.

The principal activities of the association include the following:

- publishing the AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS;
- planning and conducting meetings of the membership in August and December;
- sponsoring annual awards for the outstanding article published in the JOURNAL, for the three best doctoral theses and the three best masters theses in the field of agricultural economics, for three outstanding reports of research in the field, for distinguished teaching in the field, and for outstanding extension programs;
- stimulating interest in agricultural economics among undergraduate students;
- publishing periodically a biographical directory of the association's membership;
- recognizing outstanding agricultural economists through an honorary Fellows program.

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Membership in the association is open to persons having a professional interest in agricultural economics. Dues are payable at the beginning of each calendar year. The rates are as follows:

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Applications for membership, payment of dues, changes in address, or inquiries regarding the general affairs of the association should be addressed to John C. Redman, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky 40506. Students applying for junior memberships should use application forms available from and signed by the head of the department in which they are studying.